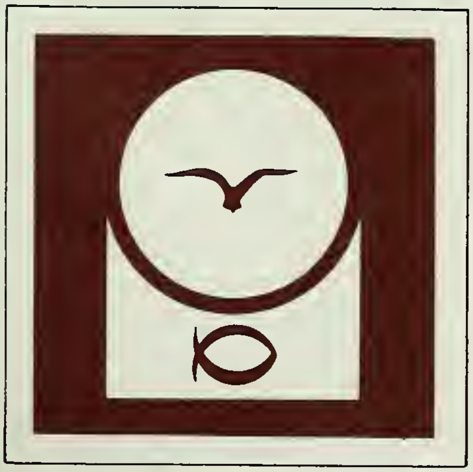


Analysis of the Impact of Coal Trains Moving Through Morehead City, North Carolina

Wang Engineering Co., Inc.
119 West Maynard Road
Cary, NC 27511

OCTOBER 1982

North Carolina
Coastal Energy Impact Program
Office of Coastal Management
North Carolina Department of Natural Resources
and Community Development

CEIP REPORT NO. 25

To order:

Residents of North Carolina may receive a single copy of a publication free upon request. Non-residents may purchase publications for the prices listed. Because of the production costs involved, some of the publications carry a minimal charge regardless of residency. Prices for these are indicated in the price list as being "for all requests".

When ordering publications please provide the publication number and title and enclose a check made payable to DNRCD. For a complete list of CEIP publications - or to place an order - contact:

Coastal Energy Impact Program
Office of Coastal Management
N.C. Department of Natural
Resources and Community
Development
Box 27687
Raleigh, NC 27611

Series Edited by James F. Smith
Cover Design by Jill Miller

ANALYSIS OF THE IMPACT OF COAL TRAINS MOVING THROUGH MOREHEAD CITY, NORTH CAROLINA

BY

WANG ENGINEERING CO., INC.
119 West Maynard Road
Cary, North Carolina 27511

The preparation of this report was financed through a Coastal Energy Impact Program grant provided by the North Carolina Coastal Management Program. The CEIP grant was part of NOAA grant NA-81-AA-D-CZ124.

Project No. 81-06

Contract No. C-6105

October 1982

CEIP REPORT NO. 25

ACKNOWLEDGEMENT

This report is the results of a study funded by Coastal Energy Impact Program (CEIP) which is managed by the Office of Coastal Management, North Carolina Department of Natural Resources and Community Development. The in-kind service match was provided by the staff members of the Town of Morehead City.

We would like to extend our appreciation to Honorable Edward S. Dixon, Mayor of Morehead City, and the Council members for their encouragement and direction; Mr. Donald T. Davis, Administrator of Morehead City, and his staff members at the Police Department, Utility Department and Building Permit Department for their vital assistance in data collection and field measurements.

Our special thanks to Mr. George Sherrill, Coordinator of N. C. Noise Control Program for his efforts in conducting the noise measurements at the Town of Morehead City. We are grateful for the assistance from Jim Smith, CEIP coordinator.

ABSTRACT

At the present time 3 million tons of coal is transported by trains through Morehead City each year. This is projected to rise to 15 million tons per year by 1984. As the tonnage of exported coal increases, the possible adverse effects on the Town of Morehead City are likely to be observed.

This report examines the possibility of any adverse effects to the Town and its citizens caused by the coal train transportation. Traffic delay, noise and vibration, and business effect studies were conducted, analyzed, and conclusions drawn from these studies to assess the impacts.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

SUMMARY

Through the detailed study of normal traffic delay, emergency traffic delay, noise and vibration impacts, and business effects for coal train movements through the Town of Morehead City, the following summary was derived:

1. The schedule of train movements through Morehead City will have a critical impact to the normal and emergency traffic delay. For example the 15 million coal tons per year will delay 482 vehicles daily at 24th Street in July, if the trains are scheduled to pass through Morehead City during the daytime. Under the same conditions, 158 vehicles will be delayed if the trains are scheduled, to pass during the nights. Up to 30 minutes of traffic delay has been experienced at 4th Street crossing attributed to rearrangement of train cars near the State Port.

2. No significant impact to the emergency traffic except limited effect to rescue squad was found for train transporting 3 million tons of coal through Morehead City, but the impact may increase as the coal tonnage increases.

3. The average noise levels from train movements are substantially higher than those from highway vehicles; 59 dBA to 76.3 dBA from the train movements comparing to 47 dBA to 67 dBA at normal time. The existing train noise does not exceed the annoying level of 80 dBA which was established by the EPA. The increase of train frequency and therefore prolongation of train noise could cause an unpleasant atmosphere for local residents.

4. The train contributed ten times more peak soil particle velocity than that from the normal highway vehicles within 100 feet from the vibration source. No serious impact to the safety of above ground structures is observed, but long range effects to the uneven settlement of soil underneath the water and wastewater lines could cause the increase of bending force on the lines and joints with eventual water leakage. More frequent train transportation will accelerate this process.

5. The effects of train vibration upon residence along Arendell Street range from just perceptible to easily noticeable. The combination of noise and vibration will increase the resident's annoyance, especially at night.

MITIGATION AND ALTERNATIVES

To reduce the transportation impact, the arrangement of train schedules is very critical. To allow the train to pass through the Town of Morehead City during rush hours should definitely be avoided. The further improvements of rail beds, and control of train speeds will have a positive effect to the mitigation of noise and vibration impacts attributed to the coal train movements.

The substantial increase of coal train movement frequency through the Town of Morehead City will have a great impact to the local traffic, quality of living conditions, safety of water and wastewater lines adjacent to the railroad, and local and tourist business. Consequently, studies have been conducted by the N. C. Department of Transportation, and UNC Institute for Transportation Research and Education to evaluate the various alternatives for increasing coal exportation:

1. Build the railroad tracks around the Town of Morehead City with several prospective routes.

2. Use belt conveyors through the Town of Morehead City.

3. Develop rail cars on barge system around the Town of Morehead City.

4. Establish coal on barge system around the Town of Morehead City.

5. Adopt pulverized coal slurry pipeline through the Town of Morehead City.

6. Build barge particle coal slurry pipeline through the Town of Morehead City.

7. Use pneumatic coal transporting pipeline through the Town of Morehead City.

The technical and economic feasibility of these alternatives are under evaluation, which is beyond the scope of work for this contract.

COAL TRANSPORTATION IN COASTAL NORTH CAROLINA

In 1980 and 1981 the State of North Carolina was faced with numerous proposals for large-scale facilities for shipping coal from North Carolina ports. Transportation of this coal through the coastal zone would affect many communities along the rail lines. It would also affect the terminal cities--Morehead City and Wilmington--through both rail traffic and port development. In order to prepare state and local agencies for dealing with these impacts, a major effort was organized under the sponsorship of the Coastal Energy Impact Program to discover these impacts, quantify and analyze them, and to propose mitigation measures. This present report is one of four reports which have resulted from this effort. In addition, closely related reports have been prepared on port development at Radio Island near Morehead City, alternative technologies for moving coal, and the alternative of wide-beam shallow-draft colliers for Wilmington. Those reports are listed in the list of CEIP Publications in the back of this report.

<u>Impacts of Increased Rail Traffic on Communities in Eastern North Carolina</u> (CEIP Report No. 17)

This study estimates the positive and negative impacts of increased rail traffic on communities in eastern North Carolina. The positive impacts include estimates of rail and port-related employment and payroll increases that could be expected if major increases in the annual volume of any bulk commodity, such as coal, were to be exported from Morehead City or Wilmington. The negative impacts focus on vehicle/train, at-grade crossing conflicts, such as traffic delay, emergency vehicle delay, accidents, fuel use, and pollution. Alternative solutions are suggested for the problems various specific communities may encounter.

A case study approach has been taken in this study, with ten local communities providing data for analysis. Seven "problem specific" solutions to increased rail traffic in these communities were analyzed: rail by-pass, grade separation, street widening, emergency services/railroad communications, fire/medical services for isolated neighborhoods, grade crossing warning devices, and city ordinances. Needs for these types of improvements in the towns of New Bern and Morehead City alone total about $90,000,000. In the other eight case study communities, needs for capital improvements to accommodate increased rail traffic total approximately $16,000,000. These needs are based on an assumed 20 million tons of export commodities annually through <u>either</u> of the two port cities (Morehead City or Wilmington). On the basis of these results, major commodity flows in the Wilmington rail corridor would fewer vehicle/train impacts than rail traffic in the Morehead City corridor. All other factors being equal, it is recommended that priority be given to promoting rail traffic in the Wilmington corridor.

<u>Analysis of the Impact of Coal Trains Moving through Morehead City</u> (CEIP Report No. 25)

This report examines the possibility of any adverse effects to the town of Morehead City and its citizens caused by the coal train transportation. Impacts are estimated for tonnages of three million and 15 million tons of coal per year. Field measurements under current conditions (coal trains at about a one million ton per year rate) were made of vibration and traffic. Traffic delay and business effect studies were also conducted. Special attention was given to the impacts of train-caused vibrations on utility lines buried under or near the tracks.

Coal Movements through the City of Wilmington (CEIP Report No. 26)

This study identifies and analyzes the potential economic, transportation, and environmental impacts to the City of Wilmington caused by the export of coal through the State Port. Primary attention focuses on the effects of unit train movements. Special attention is given to effects on several neighborhoods which were chosen to reprent the full array of socio-economic patterns found along the rail line. Public policy actions are recommended to reduce adverse impacts.

New Bern Coal Train Study (CEIP Report No. 24)

This project, which is still underway, studies the impacts of coal trains on historic structures in New Bern. Extensive vibration studies and engineering analyses of historic buildings have been undertaken. Protective measures are expected to be recommended.

I. INTRODUCTION

The United States did not export any steam coal in 1978 and exported 2.5 million tons in 1979. However, the National Coal Association projects that steam coal exports will reach 25 to 53 million tons annually by 1985, and 60 to 79 million tons annually by 1990. (NCDOT report, June 1982). The UNC Institute for Transportation Research and Education (ITRE) reported that various projections indicated the United States will export about 39.1 million tons of steam coal annually by 1990.

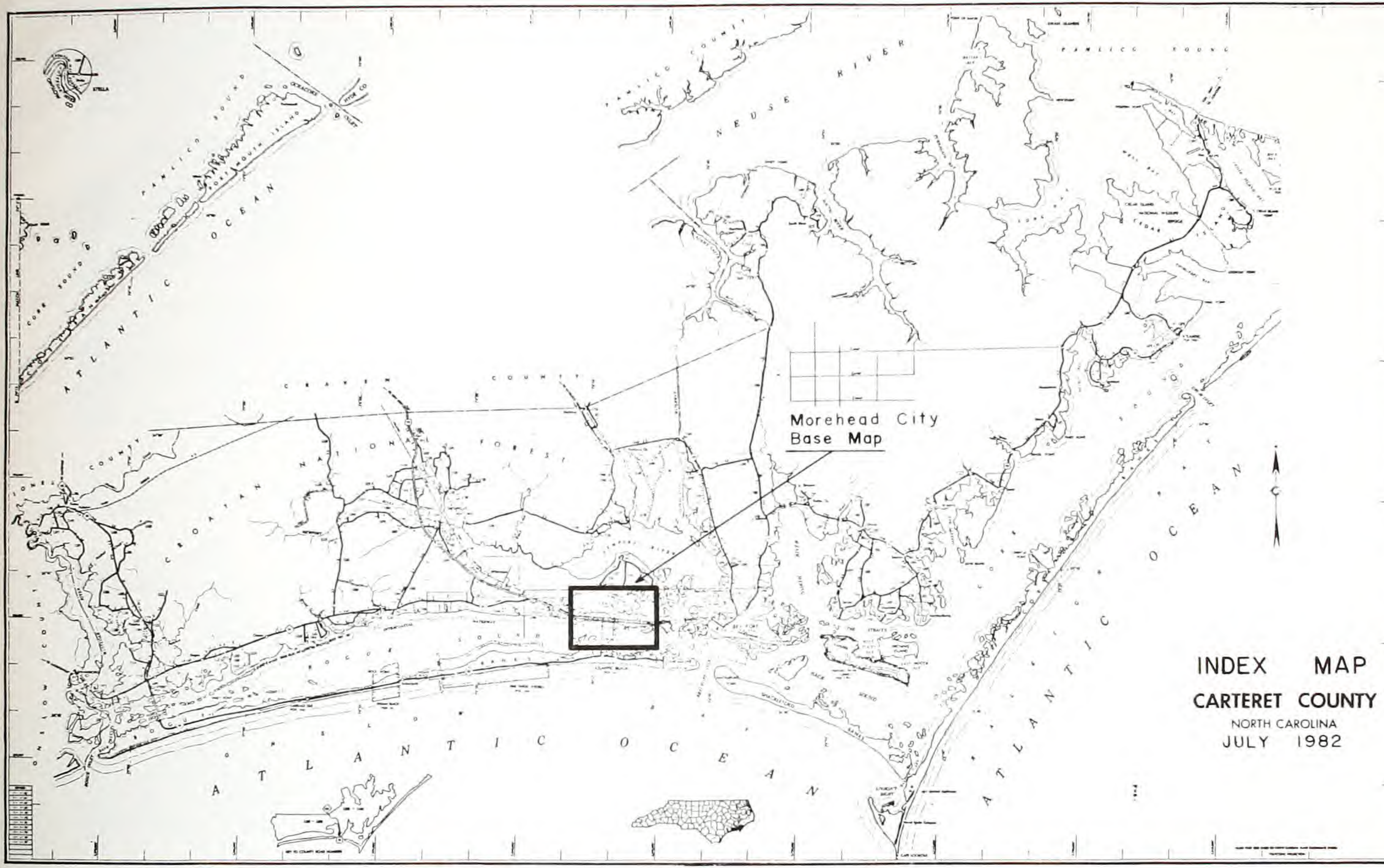
It was estimated that a certain tonnage of this coal would be exported through North Carolina ports, especially through the Town of Morehead City and City of Wilmington. A contract was signed between Alla-Ohio Valley Coals, Inc. and N. C. State Port Authority to export 3 million tons of coal annually through the Morehead City Port. In October 1981, the Coastal Resources Commission voted to reclassify Radio Island from a "Rural" to "Rural Port" classification, subject to satisfactory findings from two study reports.

The existing mass transportation system for Morehead City Port is the railroad train passing through the center of the Town of Morehead City.

This report is the results of a study funded by Coastal Energy Impact Program with the in-kind service assistance from the Town of Morehead City. To evaluate the environmental safety and economical impact attributed to the existing and possibly increasing coal train movements through the Town of Morehead City, this study consists of the following analysis:

1. Traffic Impact
2. Emergency Traffic Impact
3. Noise Impact
4. Vibration Impact
5. Business Effects
6. Mitigation and Alternatives

The study area for this report is the 3 mile railroad track with 27 street crossings and the adjacent areas within Morehead City Limits. The general location of the study area is shown on the Index Map.



Morehead City
Base Map
INDEX MAP
CARTERET COUNTY
NORTH CAROLINA
JULY 1982
ATLANTIC OCEAN
CROATAN NATIONAL FOREST
CRAVEN COUNTY
PAMLICO COUNTY
NEUSE RIVER
PAMLICO SOUND
CORE SOUND
ONSLOW COUNTY
JONES COUNTY
BOGUE SOUND

II. NORMAL TRAFFIC DELAY

The coal train movements through the Town of Morehead City could have a significant impact on traffic movements as the frequency increases. A combination of seasonal traffic data, train log data, hourly traffic data, and train delay times were used to assess the delay of traffic caused by increased coal train.

II.1. Traffic Counts at Designated Locations

A traffic survey was conducted in May of 1982 to determine the number of vehicles per hour crossing the railroad at designated locations between 4th and 35th Streets. The exact locations of these crossings are shown on Map 1 and the data is listed in Tables 1 - 6. It was found that the railroad crossings at 24th, 4th, and 35th Streets are the most crucial because of the heavy volumes of traffic flow and hospital access interruption.

The heaviest volume of traffic crossing the railroad occurred at 24th Street. On a Sunday afternoon between 4:30 and 6:00 p.m., approximately 1,566 vehicles per hour crossed the railroad tracks (Table 4). It is assumed that this traffic would predominantly be tourists from Atlantic Beach. The highest weekday traffic flow of 1,019 vehicles per hour was observed in the late afternoon, while the least amount of traffic at the 24th Street crossing was in the late evening and early morning hours, as expected, with a volume of 230 vehicles per hour.

At the 4th Street railroad crossing, the peak traffic volume was 742 vehicles per hour (Table 1) on a weekday afternoon. The least volume was in the late evening and early morning hours when a volume of 154 vehicles per hour was recorded crossing the railroad.

The crossing at 35th Street has less traffic than that at 4th and 24th Streets, but it is a significant crossing due to its access to the hospital. During the traffic survey, the heaviest traffic occurred on a Friday afternoon when 547 vehicles crossed the railroad per hour; the least amount of traffic crossing this intersection was in the late evening and early morning hours with an average of 50 vehicles per hour. The interruption of normal traffic at this intersection is not as serious as the 4th and 24th Street crossings, but rather the disruption of emergency medical vehicle access to the hospital is more of a concern. This will be discussed in more detail in emergency traffic analysis.

II.2. Seasonal Traffic Adjustment Analysis for Designated Locations

Morehead City, being a center for recreation, has its highest amount of traffic in the summer months, due to increasing tourists activities. In a traffic study conducted in 1981 by the North Carolina Department of Transportation, the highest seasonal peak occurred in June with a weekend volume of about 27,000 Average Daily Traffic (ADT) and a weekday peak of about 22,000 ADT (Figure 1). A significant traffic

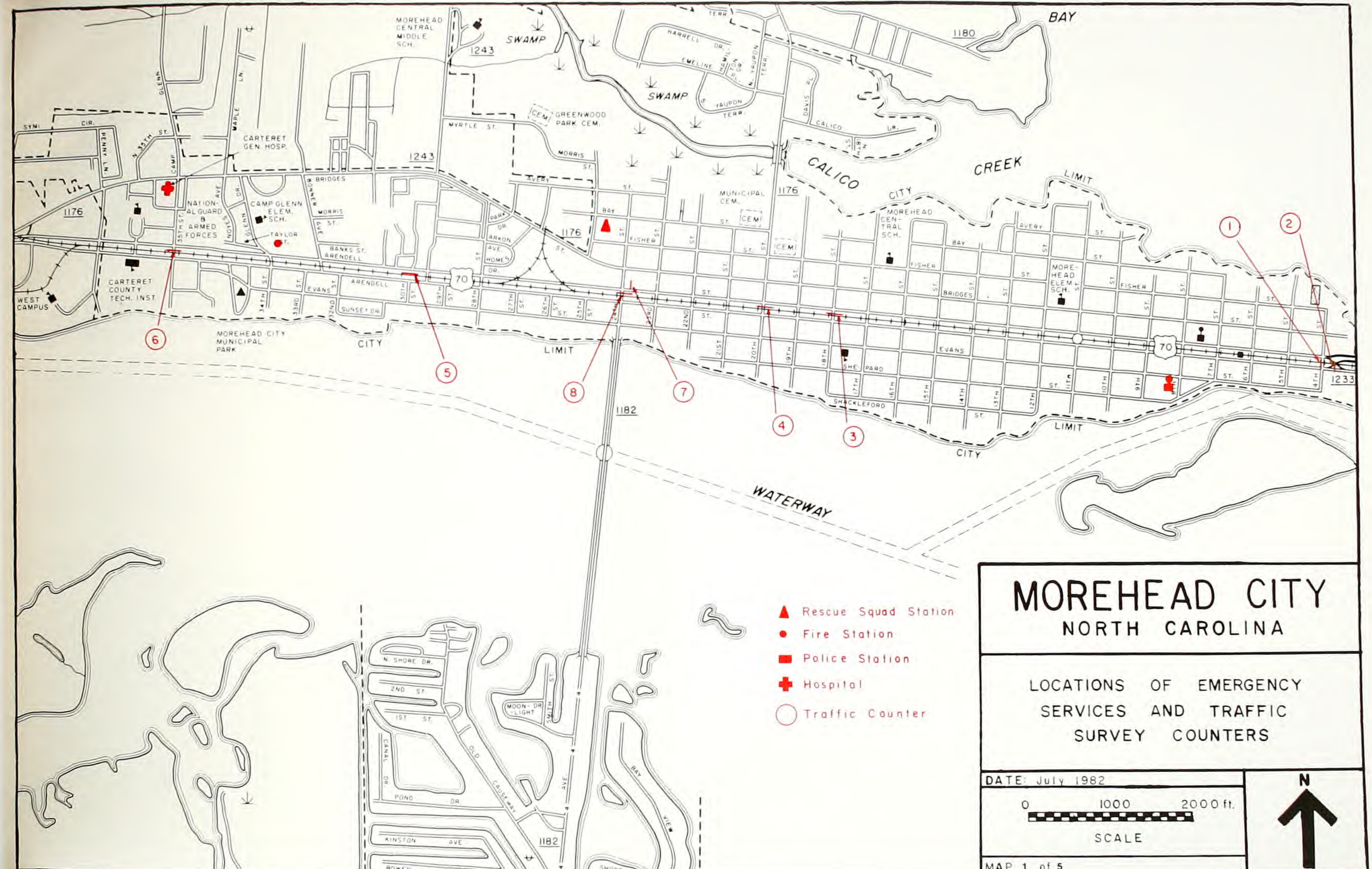

MOREHEAD CITY
NORTH CAROLINA
LOCATIONS OF EMERGENCY SERVICES AND TRAFFIC SURVEY COUNTERS
DATE: July 1982
0 1000 2000 ft.
SCALE
MAP 1 of 5
N
Rescue Squad Station
Fire Station
Police Station
Hospital
Traffic Counter
WATERWAY
CALICO CREEK
BAY
SWAMP
CITY LIMIT
CARTERET GEN. HOSP.
CARTERET COUNTY TECH. INST.
WEST CAMPUS
MOREHEAD CITY MUNICIPAL PARK
MOREHEAD CENTRAL MIDDLE SCH.
GREENWOOD PARK CEM.
MUNICIPAL CEM.
MOREHEAD CENTRAL SCH.
MOREHEAD ELEM. SCH.
CAMP GLENN ELEM. SCH.
NATIONAL GUARD & ARMED FORCES
ARENDELL
EVANS
SHACKLEFORD
FISHER
BRIDGES
70
1176
1243
1182
1180
1233

Table 1. Traffic Survey of Railroad Crossing at 4^{th} Street, Morehead City

Date	Time	Counter #1 Reading*	Counter #2 Reading**	Calculated Vehicles Crossing R.R.	Calculated Vehicle Traffic per hr. Crossing R.R.
5/13/82 Thursday	7:31 A.M.	4,584	447		
				572	512
	8:38 A.M.	5,938	658		
				4,190	541
	4:23 P.M.	15,155	1,495		
				1,113	742
	5:53 P.M.	17,456	1,570		
				2,100	154
5/14/82 Friday	7:30 A.M.	22,057	1,972		
				488	450
	8:35 A.M.	23,211	2,150		
				4,663	571
	4:45 P.M.	33,436	3,050		
				3,625	235
5/15/82 Saturday	8:10 A.M.	41,262	3,627		
				306	282
	9:15 A.M.	41,908	3,662		
				3,799	524
	4:30 P.M.	49,813	3,970		
				741	494
	6:00 P.M.	51,355	4,030		
				2,722	202
5/16/82 Sunday	7:30 A.M.	57,168	4,399		
				311	155
	9:30 A.M.	57,826	4,436		
				2,811	397
	4:35 P.M.	63,666	4,655		
				610	366
	6:15 P.M.	64,927	4,697		

* 4th Street & Arendell Street, Eastbound lane
** State Port Road & Arendell Street

Table 2. Traffic Survey of Railroad Crossing at 18th Street, Morehead City

Date	Time	Counter #3 Reading*	Calculated Vehicles Crossing R.R.	Calculated Vehicle Traffic per hr. Crossing R.R.
5/9/82 Sunday	7:35 A.M.	517		
	8:30 A.M.	540	12	13
	4:33 P.M.	1,129	295	37
	6:08 P.M.	1,215	43	27
5/10/82 Monday	7:22 A.M.	1,471	128	10
	8:30 A.M.	1,530	30	26
	4:35 P.M.	2,219	345	43
	5:56 P.M.	2,367	74	55
5/11/82 Tuesday	7:29 A.M.	2,669	151	11
	8:30 A.M.	2,706	19	19
	4:31 P.M.	3,243	269	34
	5:54 P.M.	3,377	67	48
5/12/82 Wednesday	7:40 A.M.	3,652	138	10
	8:31 A.M.	3,712	30	35
	4:27 P.M.	4,197	243	31
	5:49 P.M.	4,315	59	49

*18th Street & Arendell Street

Table 3. Traffic Survey of Railroad Crossing at 20^{th} Street, Morehead City

Date	Time	Counter #4 Reading*	Calculated Vehicles Crossing R.R.	Calculated Vehicle Traffic per hr. Crossing R.R.
5/9/82 Sunday	7:28 A.M.	875		
	8:25 A.M.	914	20	20
	4:31 P.M.	1,799	443	55
	6:05 P.M.	2,019	110	69
5/10/82 Monday	7:19 A.M.	2,722	352	27
	8:28 A.M.	2,863	71	62
	4:32 P.M.	4,069	603	75
	5:53 P.M.	4,344	138	102
5/12/82 Tuesday	7:27 A.M.	4,988	322	24
	8:27 A.M.	5,163	88	88
	4:29 P.M.	6,261	549	68
	5:52 P.M.	6,651	150	108
5/12/82 Wednesday	7:38 A.M.	7,401	420	31
	8:29 A.M.	7,543	71	84
	4:25 P.M.	8,946	702	89
	5:43 P.M.	9,260	157	121

*20th Street & Arendell Street

Table 4. Traffic Survey of Railroad Crossing at 24th Street, Morehead City

Date	Time	Counter #7 Reading*	Counter #8 Reading**	Calculated Vehicle Crossing R.R.	Calculated Vehicle Traffic per hr. Crossing R.R.
4/30/82 Friday	4:20 P.M.	0	0		
	6:00 P.M.	970	4,367	1,699	1,019
5/1/82 Saturday	10.30 A.M.	5,557	8,492	Traffic counter was out of order	
	4:30 P.M.	9,121	24,730	6,337	1,056
	6:00 P.M.	9,886	29,597	2,051	1,367
5/2/82 Sunday	7:30 A.M.	14,463	47,650	6,738	499
	8:50 A.M.	14,727	48,711	399	299
	4:30 P.M.	18,110	67,859	7,883	1,028
	6:00 P.M.	18,566	73,013	2,349	1,566
5/3/82 Monday	7:40 A.M.	20,272	83,009	4,145	303
	8:30 A.M.	20,472	84,239	515	618
	4:30 P.M.	23,675	97,441	5,000	625
	6:00 P.M.	24,501	100,602	1,168	778
5/4/82 Tuesday	7:30 A.M.	26,247	108,557	3,105	230
	3:30 P.M.	29,251	121,194	4,817	602

*Arendell Street at Dairy Queen, left-turn, West bound
**24th Street & Arendell Street

Table 5. Traffic Survey of Railroad Crossing at 30th Street, Morehead City

Date	Time	Counter #5 Reading*	Calculated Vehicles Crossing R.R.	Calculated Vehicle Traffic per hr. Crossing R.R.
5/4/82 Tuesday	4:30 P.M.	1,155		
			596	37
5/5/82 Wednesday	8:30 A.M.	2,346		
			1,297	185
	3:30 P.M.	4,939		
			652	261
	6:00 P.M.	6,242		
			595	44
5/6/82 Thursday	7:30 A.M.	7,432		
			80	80
	8:30 A.M.	7,591		
			1,314	158
	4:50 P.M.	10,219		
			595	510
	6:00 P.M.	11,409		
			400	30
5/7/82 Friday	7:30 A.M.	12,208		
			56	56
	8:30 A.M.	12,320		
			1,023	146
	3:30 P.M.	14,366		
			462	220
	5:36 P.M.	15,290		
			537	39
5/8/82 Saturday	7:30 A.M.	16,363		
			99	99
	8:30 A.M.	16,561		
			1,439	221
	3:00 P.M.	19,439		

*30th Street & Arendell Street

Table 6. Traffic Survey of Railroad Crossing at 35th Street, Morehead City

Date	Time	Counter #6 Reading*	Calculated Vehicles Crossing R.R.	Calculated Vehicle Traffic per hr. Crossing R.R.
5/4/82 Tuesday	4:30 P.M.	631		
			645	40
5/5/82 Wednesday	8:30 A.M.	1,921		
			1,169	167
	3:30 P.M.	4,258		
			591	236
	6:00 P.M.	5,439		
			675	50
5/6/82 Thursday	7:30 A.M.	6,789		
			177	177
	8:30 A.M.	7,143		
			1,227	175
	3:30 P.M.	9,596		
			735	294
	6:00 P.M.	11,066		
			650	48
5/7/82 Friday	7:30 A.M.	12,366		
			193	193
	8:30 A.M.	12,752		
			1,211	173
	4:36 P.M.	16,377		
			602	547
5/8/82 Saturday	7:30 A.M.	18,364		
			994	67
	8:30 A.M.	18,545		
			1,409	217
	3:00 P.M.	21,362		

*35th Street & Arendell Street

decline was observed from summer to winter. The least volume of flow occurred in December and January when the average weekday flow was about 7,200 ADT. Consequently, the traffic delay and congestion attributed to the summer heavy traffic and train movements could have a significant impact to the tourist and downtown business activities.

By using the peak and off-peak flows from the traffic survey conducted in May of 1982 and the seasonal traffic survey collected in 1981, projections were made to determine the heaviest and lowest traffic volumes during the peak traffic season expected to occur in July of 1982. From Figure 1 an increase of 8.3% is expected in the weekend traffic from May to July. An increase of 37.5% weekday traffic is projected to occur from May to July. Using these projected increases in traffic, mainly due to increased tourists, the traffic volume crossing the railroad at 24th Street would increase to 1,690 vehicles per hour during peak flow on weekends, 1,375 vehicles per hour during the peak weekday flow, and 316 vehicles per hour during off-peak flow periods.

At the 4th Street railroad crossing, the peak traffic flow was assumed to increase 8.3% on weekends and 37.5% on weekdays from May to July. Based on this assumption, this would increase the peak flow in July to 1,030 vehicles per hour on weekdays and 569 vehicles per hour on weekends. The least traffic volume expected to cross the railroad would be 169 vehicles per hour at night. By using these projected increases due to seasonal change, the traffic delay can thereafter be analyzed under the busiest conditions.

II.3. Train Log Data and Delay Time

The Morehead City Police Department provided data on train movements through the City for 1981 (Appendix A). This data gave the location, time, number of cars per train, and speed of the trains. The overall average speed of the trains passing through the City was 12.6 m.p.h. while at the crossings of 24th and 4th Streets the average speeds were 15 m.p.h. and 10 m.p.h., respectively. These train speeds were used to calculate the number of cars delayed at these crossings.

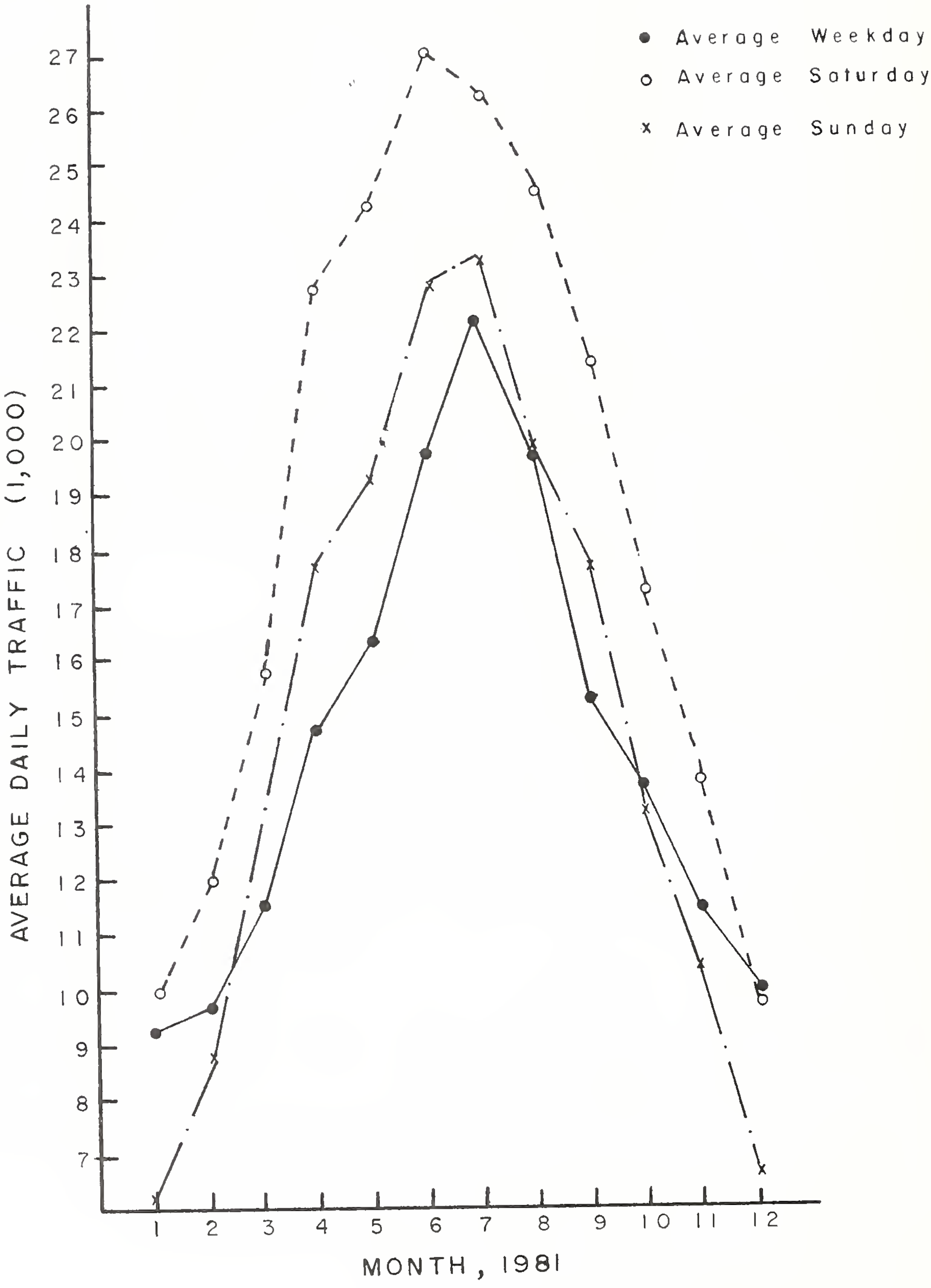
By using the traffic survey collected for the peak traffic season, the busiest conditions for traffic delay were examined. These in combination with train data on speed and length of the train, and yearly coal tonnages were used to calculate the time and number of vehicles delayed per day.

The number of unit trains required to transport 3 million, 5 million, 10 million, and 15 million tons of coal per year were estimated and is presented in Table 7.

The average train was assumed to be 80 cars in length with an estimated 100 tons of coal per car. The time delay caused by a train

Figure 1. Average Daily Traffic North

End Atlantic Beach Bridge



crossing an intersection was calculated for assumed yearly tonnages and is shown in Table 8. Train speeds of 5, 10, 15, and 20 m.p.h. were used to calculate the delays.

With a volume of 3 million tons of coal being transported through Morehead City per year, which is equivalent to about one train per day in each direction, the traffic delay per day would be 6 minutes for the trains moving at a speed of 15 m.p.h. This delay would increase for slower trains and is represented in Table 8. A speed of 15 m.p.h. is the maximum allowable velocity for trains under the Morehead City Code from 24th Street eastward.

At speed of 15 m.p.h. at the 24th Street intersection a train during the peak flow of 1,690 vehicles per hour in July would cause a delay of 85 vehicles. During normal mid-day traffic of approximately 860 vehicles per hour, a train would delay 43 vehicles; while in the off-peak flow period of 316 vehicles per hour, only 16 vehicles would be delayed. The delay at the 4th Street railroad crossing caused by a train moving at 10 m.p.h., which is the average speed determined from train data provided by the Morehead City Police Department, would be 86 vehicles during peak flow, 46 vehicles during mid-day traffic, and 14 vehicles would be delayed during off-peak flow. The number of vehicles delayed was calculated for one train with 80 coal cars. Since 3 million tons are to be transported through the city, two trains per day are required to pass these intersections. If both trains crossed these intersections during peak traffic hours, the maximum number of vehicles that could be delayed per day is 170 vehicles at the 24th Street intersection and 172 vehicles per day at the 4th Street intersection. The estimated number of vehicles which will be delayed by each train movement at 4th, 24th, and 35th Streets for projected months of January and July are presented in Table 9. The average train speed at 4th Street crossing was estimated to be 10 m.p.h., and 15 m.p.h. at 24th and 35th Street crossings were assumed.

While only 3 million tons of coal per year are moving through the City, the vehicle delay is insignificant, but as the tonnage of coal per year increases, a significant increase in delay occurs. With an estimated 15 million tons of coal to be transported through the City per year, or 5 trains per day in each direction by 1984, as projected by the University of North Carolina Institute for Transportation Research and Education (ITRE), the traffic delay would increase 5 times to 30 minutes per day.

II.4. Discussion

Currently, the train passes two times a day, once in each direction through the Town of Morehead City. With an increase of train movements above 2 trains per day, the increase could have a significant impact on the traffic delay. However, if train movements through the City could be scheduled for off-peak traffic hours, particularly at nights and early

Table 7. Calculation of Coal Trains Passing Through the Town of Morehead City

Assumed Coal Tonnage per year (million tons)	3	5	10	15
Coal Tonnage Per Car	100	100	100	100
No. Cars Per Train	80	80	80	80
Average Length of Train (ft.)	4240	4240	4240	4240
Calculated Trains Per Day (Both Ways)	2	4	6	10

Assumptions
1) average length coal train car 53ft.
2) 100 tons of coal per car
3) each train 80 cars long

Table 8. Train Time Delay Per Day

	3 million tons per year			10 million tons per year			15 million per year		
Speed of Train (mph)	Number trains per day*	Time delay per train	Total time delay/ day	Number trains per day*	Time delay per train	Total time delay/ day	Number trains per day*	Time delay per train	Total time delay/ day
5	2	10min.	20min.	7	10min.	70min.	10	10min.	100min.
10	2	5min.	10min.	7	5min.	35min.	10	5min.	50min.
15	2	3min.	6min.	7	3min.	21min.	10	3min.	30min.
20	2	2.5min.	5min.	7	2.5min.	175min.	10	2.5min.	25min.

*number of trains both ways

Table 9. Estimated Number of Vehicles Delayed Per Train Movement Through Morehead City

Location and time		January Weekday	January Saturday	July Weekday	July Saturday
*4th Street	Rush hour	36	18	86	47
	Daytime	27	15	64	42
	Night	7	5	18	14
**24th Street	Rush hour	29	31	69	85
	Daytime	19	20	45	54
	Night	7	7	16	20
**35th Street	Rush hour	16	No Data Recorded	38	No Data Recorded
	Daytime	5		12	
	Night	1		3	

* Average speed of train - 10 mph

** Average speed of train - 15 mph

mornings, the impact of traffic delays could be greatly reduced. As transporting coal tonnages and the train frequency increase, the scheduling of train movements for off-peak traffic periods will become more critical. For example, when 15 million tons of coal per year are transported through the City with the assumption of 5 trains during normal mid-day traffic and 5 trains moved through the City during the night and early morning hours, the vehicles delayed in July would be 294 vehicles per day at the 24th Street crossing and 300 vehicles per day at the 4th Street railroad crossing. However, if the train movements are scheduled during peak traffic hours, the delayed vehicles will be substantially higher.

By discussing with the Morehead City officials, we found one of the major traffic delays at 4th Street is due to the switch of train cars and make up of the train near State Port . The delay can last as long as 30 minutes at one time.

III. EMERGENCY TRAFFIC DELAY

The delay of emergency traffic by train movements through the Town of Morehead City may have an adverse impact to the life and property protection of the local community. To assess the impact of emergency service delay, such as fire, police, and rescue squads, the 1981 emergency calls data prepared by the Morehead City Emergency Services were collected and analyzed. The date, time, and locations of emergency events are listed in Appendix B, C, and D. The emergency traffic impact attributed to train movement was thereafter studied.

III.1. Fire Emergency Traffic

Since there is a fire station on each side of the railroad, the interruption and delay of fire services are the least affected emergency traffic by coal trains passing through the City. The location of fire stations is shown on Map 1. Data supplied by the Morehead City Fire Department for the months of April and September of 1981, showed that a large majority of fires occurred north of the railroad tracks and were usually consisting of brush fires or small fires in residential homes. If a fire did occur that required both fire stations to respond while a train was in the area, the fire equipment that must cross the railroad tracks could use an alternate route around the train, while the other fire station's equipment responded to the fire. For example, if fire equipment was dispatched from the fire station south of the railroad tracks to the Morehead City Recreation Center while a train is eastbound and blocking the 8th Street intersection, it would be necessary for the emergency vehicles to detour behind the train. The normal route for the fire trucks would be 8th Street, Arendell Street to 16th Street to Fisher Street. If the fire trucks average speed is 30 m.p.h., the response time would be approximately 1.8 minutes; with the moving train, the detour route could be 8th Street, to Evans Street, to 16th Street, and to Fisher

Street. This would also result in an approximate response time of 1.9 minutes, thus uneffecting emergency fire services.

If the train was westbound and blocking 8th Street and the fire equipment was making the same response as before there are two choices of action. The equipment could detour behind the train and possibly wait at the 4th Street crossing for the train to pass or the fire equipment could try to outrun the train and detour ahead of the train. Trying to outrun the train would be the quickest route to take, with a response time of approximately 2 minutes, but attempting to detour in front of the train would risk the safety of the firemen as well as the normal traffic.

III.2. Police Emergency Traffic

Another possible effect trains could have on emergency services is the delay of police traffic. The police station is located one block south of Arendell Street on 8th Street (Map 1). To reduce the adverse impact of train movements, it is suggested to have the police patrol the City and provide emergency aid on both sides of the railroad tracks. According to the data supplied by the Morehead City Police Department on responses to wrecks, 73% occurred north of the railroad tracks. The availability of police aid at these emergencies should not be effected by trains if policemen are constantly patrolling on both sides of the railroad tracks. In the event of a wreck, the more important issue is the transportation of injured persons to the hospital by rescue squads.

III.3. Rescue Squad Emergency Traffic

Trains moving through the City while a rescue squad is en route to an emergency center or to the hospital could cause victims to lose valuable time in receiving emergency aid. The Morehead City Rescue Squad provided data for the month of September of 1981, giving the locations of emergency aid responses (Appendix D). The location of the rescue squad station is shown on Map 1. From a total of 40 responses for that month, 75% were north of the railroad tracks. These responses will be unaffected by trains since the hospital is also located north of the railroad tracks (Map 1).

If an accident occurred on the southern side of 24th Street at the Atlantic Beach Bridge, the rescue squad must cross the tracks en route to the emergency and to the hospital. From the rescue squad station on 25th Street, the quickest route to the emergency would be Bridges Street to 23rd Street to Evans Street and 24th Street. However, it should be noted that the Evans Street to 24th Street is blocked by barricades in some months of the year. For the rescue squad speed averaging 35 m.p.h., the response time would be approximately 1.3 minutes. If a westbound train was blocking the 23rd Street intersection the safest detour would be behind the train. Detouring to 16th Street from the rescue squad station to cross the tracks would result in a response time of 3.4 minutes.

Transporting the victim to the hospital from the Atlantic Beach Bridge would also cause the rescue squad to cross the railroad tracks. An assumed route to the hospital could be to cross the tracks at 24th Street, resulting in a response time to the hospital of approximately 2.6 minutes for the rescue squad speed averaging 35 m.p.h. If we assume the train is westbound, detouring in front of the train and attempting to cross the tracks at 35th Street would not delay the emergency vehicle, but would depend on whether the vehicle could outrun the train without causing an accident with normal traffic. The safest route to the hospital would be to detour behind the train until a clear crossing is found. If the emergency vehicle crossed the tracks at 17th Street, the response time to the hospital increases 2 minutes. An increase of approximately 2 minutes to either the emergency or the hospital may not be an excessive delay.

The safety of a rescue squad detouring to avoid delay by trains depends on the traffic volume at the time. If the response is made in the early morning hours while the traffic volume is low, almost any intersection could be used to cross the railroad tracks. When the response is made in the late afternoon when the traffic volume is at a peak, heavily traveled intersections such as 4th and 24th Streets should be avoided. An emergency vehicle could make motorists nervous, making it necessary for the rescue squad to reduce speed to avoid accidents. The intersections of 18th, 20th, 30th, and 35th Streets have considerably less traffic than those of 4th and 24th Streets and if used by rescue vehicles would avoid heavy traffic and reduce the time delay.

III.4. Discussion

The analysis indicates that no significant impact is observed for fire and police emergency services under the existing condition (3 million tons of coal shipment per year, two trains a day). However, some delay of rescue vehicles (4 minutes for both directions) was recognized for victims located south of railroad tracks near the Atlantic Beach Bridge. To avoid the emergency traffic delay, it is important to schedule the train movements through the City during off-peak traffic hours.

IV. NOISE IMPACT STUDY

Excessive noise levels due to increased coal train movements is one of the major concerns of local officials and residents. To assess the extent of noise impact caused by coal trains, noise studies were conducted. These studies were compared with federal regulations on railroad noise emission for compliance with other studies on noise and possible noise related health problems.

The Southern Railroad rebuilt the railroad bed in early 1982. Consequently, substantial reduction of noise levels from train movements has been observed. The railroad improvements have been highly praised by local officials and residents.

IV.1. Noise Level Measurements

Noise level measurements were conducted in June of 1982 with the assistance from the Noise Control Program of the N. C. Department of Natural Resources and Community Development. Background noise level measurements were taken during the daytime and night hours when there were no trains in the area, and readings were also recorded when trains were moving through the City. The noise level was measured by decibel (dB).

The decibel of the quantity A relative to (re) the quantity A_o is defined as

$$\text{decibel} = 10 \text{ Log } (A/A_o) \text{ dB re } A_o$$

The decibel is used in environmental noise pollution as a measure of sound power level, sound intensity level, and sound pressure level.

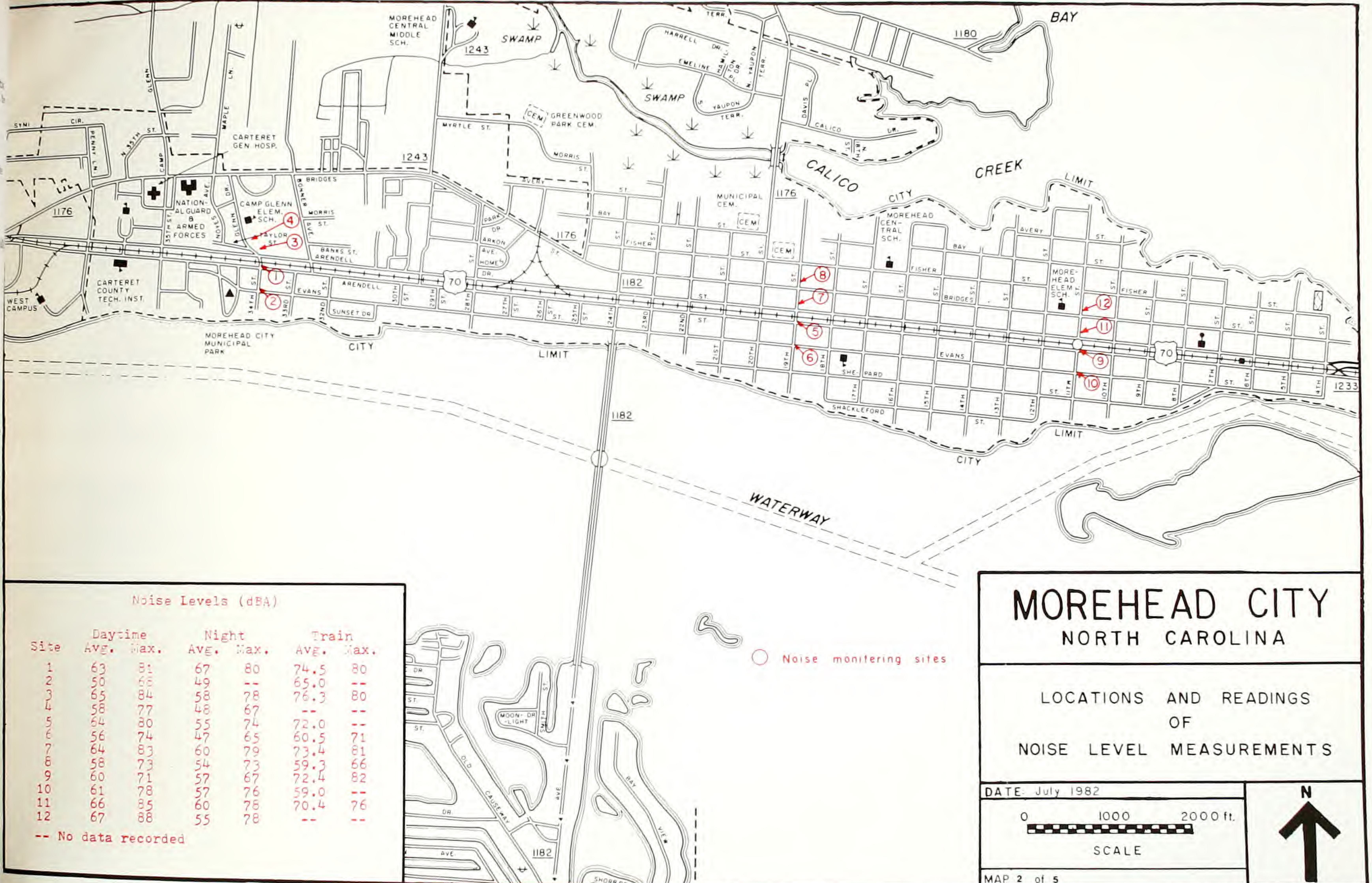
IV.1.1. Background Noise Levels

For the background sound level measurements, Metronsonics dB-306 Metrologger Integrating Sound Level Meter (Serial No. 1110) was used. The meter was set at the designated locations free of structure interference. The duration of sound recording at each location was 15 minutes.

The locations of the monitoring sites and integrated average background levels during daytime and night are shown on Map 2. Sound level monitoring was conducted at the intersections of 11th, 19th, and 34th Streets. Readings were taken on each side of the tracks approximately 100 feet and 300 feet from the tracks at all three intersections.

IV.1.2. Train Noise Levels

Because the low daily frequency of train passing through the Town of Morehead City, four monitoring stations were established at the designated locations and measured the sound levels simultaneously as the train passed by. In addition to the Metronsonic dB-306 Integrating Sound Level Meter, three manually recording meters were used; two Quest Electonics Model 215 Sound Level Meters Type II (Serial No. m 808011 and m 9080122), and one set of General Model 1565-C Sound Level Meter Type II (Serial No. 063421). For the manual meters, the sound levels in decibels average (dBA) were recorded every 10 seconds starting at the train's arrival at the monitoring station. The weighted averages of the recording data are listed on Map 2 at the corresponding stations.



Noise Levels (dBA)

Site	Daytime Avg.	Daytime Max.	Night Avg.	Night Max.	Train Avg.	Train Max.
1	63	81	67	80	74.5	80
2	50	68	49	--	65.0	--
3	65	84	58	78	76.3	80
4	58	77	48	67	--	--
5	64	80	55	74	72.0	--
6	56	74	47	65	60.5	71
7	64	83	60	79	73.4	81
8	58	73	54	73	59.3	66
9	60	71	57	67	72.4	82
10	61	78	57	76	59.0	--
11	66	85	60	78	70.4	76
12	67	88	55	78	--	--

-- No data recorded

MOREHEAD CITY
NORTH CAROLINA

LOCATIONS AND READINGS OF NOISE LEVEL MEASUREMENTS

DATE: July 1982

0 1000 2000 ft.

SCALE

N

MAP 2 of 5

IV.2. Noise Level Data Analysis

The location, weighted average dB, and maximum dB of each noise level measurement station are presented in Map 2. The data analysis for noise levels of background and train movements are followed.

IV.2.1. Background Noise Levels

At a distance of 100 feet from the railroad tracks the average noise levels were 64 dBA in the daytime and 59.5 dBA at night. The average noise levels at 300 feet from the tracks were 58.3 dBA in the daytime and 51.7 dBA at night. In general, the average noise levels, during daytime and night, are higher near Arendell Street than those 300 feet away from the railroad due to the heavier traffic. The daytime average noise levels averaged about 5 dBA and 7 dBA higher than that at night at 100 feet and 300 feet from the railroad, respectively. Noise levels recorded during the daytime and night were affected by cars, trucks, motorcycles, and jet planes. By using Figure 2 to calculate the source noise level, it is found that the daytime traffic noise levels contributing to the increase of total noise level increase are 62.2 dBA and 57.3 dBA at 100 feet and 300 feet from the railroad, respectively. There is no particular trend for the maximum noise levels being recorded at 100 feet and 300 feet from the railroad. However, the high noise levels are generated more often along Arendell Street due to heavier traffic.

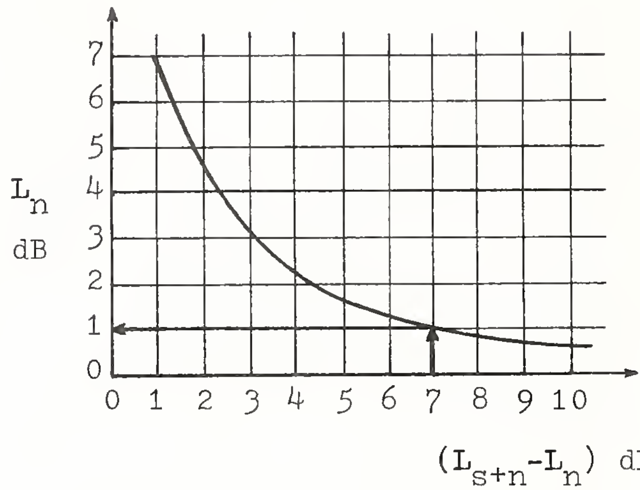
IV.2.2. Train Noise Levels

The average train noise levels were measured as 73.2 dBA and 61 dBA at 100 feet and 300 feet from the railroad, respectively. The increases of average noise level attributed to train movement are about 9 dBA at 100 feet and 2.7 dBA at 300 feet from the railroad during the daytime; the respective increases are 13.7 dBA and 9.3 dBA at night. Therefore, the increase of noise levels due to train movements is more noticeable at nights than that during the daytime. It was observed in Map 2 that the instantaneous maximum noise level being generated by train movements is not always greater than that during the daytime and night.

IV.3. Discussion

The relationship of sound levels versus human response was developed by the EPA and is listed in Table 10. The sound levels having been measured in the Town of Morehead City are: 50 dBA to 67 dBA during the normal daytime, 47 dBA to 67 dBA at nights and 59 dBA to 76.3 dBA during the train movements. Comparing to Table 10 neither the average nor the maximum noise levels being measured at designed stations, with or without the train movements, has exceeded the hearing damage level of 90 dBA.

Figure 2. Calculation of Source Noise Level From Total and Background Noise Levels



1. Measure the total noise level (L_{s+n}) with the machine running.

2. Measure the background noise level (L_n) with the machine turned off.

3. Find the difference between the two readings. If less than 3 dB, the background noise level is too high for an accurate measurement. If between 3 and 10 dB, a correction will be necessary. No correction is n necessary if the difference is greater than 10 dB

4. To make the correction, enter the bottom of the chart with the difference value from step 3, go up until you intersect the curve and then go to the left to the vertical axis

5. Subtract the value on the vertical axis (L_n) from the total noise level in step 1. This gives the noise level of the machine.

Example:

1. Total Noise = 60 dB

2. Background Noise = 53 dB

3. Difference = 7 dB

4. Correction (from chart) = 1 dB

5. Noise of Machine = 60 - 1 = 59 dB

Table 10 Sound Levels and Human Response

Common Sounds	Noise Level (dB)	Effect
Carrier deck jet operation Air raid siren	140	Painfully loud
	130	
Jet takeoff (200 feet) Thunder clap, Discotheque Auto horn (3 feet)	120	Maximum vocal effort
Pile drivers	110	
Garbage truck	100	
Heavy truck (50 feet) City traffic	90	Very annoying Hearing damage (8 hours)
Alarm clock (2 feet) Hair dryer	80	Annoying
Noisy restaurant Freeway traffic Man's voice (3 feet)	70	Telephone use difficult
Air conditioning unit (20 feet)	60	Intrusive
Light auto traffic (100 feet)	50	Quiet
Living room, Bedroom, Quiet office	40	
Library, Soft whisper (15 feet)	30	Very quiet
Broadcasting studio	20	
	10	Just audible
	0	Hearing begins

Information from "Noise and its Measurement." Environmental Protection Agency OPA 22/1, January, 1981.

In accordance with the EPA's report published in the Federal Register on Wednesday, January 14, 1976 entitled "Railroad Noise Emission Standards" stated that no train should produce noise levels in excess of 88 dBA for rail cars moving 45 m.p.h. or less and 93 dBA for rail cars moving greater than 45 m.p.h. Since the maximum allowable speed of a train moving through the Town of Morehead City is 20 m.p.h., which is specified in the Morehead City Code, the maximum noise level for any train in the City is 88 dBA measured at 100 feet from the tracks. The maximum noise level recorded by the noise study was 76.3 dBA which is well below the maximum EPA permissible level of 88 dBA. The noise study is thought to be a representative sample of all trains that would be within the City and no train is expected to produce the noise levels equal to or greater than 88 dBA.

Exposure to high noise levels can effect the general public in two ways; extreme noise levels can result in hearing loss, while moderately high levels will cause community complaints and annoyance. The EPA report entitled "Identification of Maximum Exposure Levels to Avoid Significant Adverse Effects" specified a noise level of 70 dBA as the noise level to which hearing loss could occur. This noise level is an average level for a 24 hour period. The noise study shows that at 100 feet from the tracks the noise level caused by a train will be 70 dBA or greater. While only 2 trains per day move through the City, the frequency of the noise will not be great enough to cause an average noise level for 24 hours of 70 dBA to occur, but as the frequency of the train increases the possibility of more complaints from local residents are expected.

Although hearing loss would be the most detrimental, the possibility of having resident's annoyance and complaints about noise is the more probable. The EPA report gives a noise of 55 dBA as the outdoor noise level in residential areas to which any noise level above 55 dBA would have an effect on public health and welfare due to interference with speech or other activity.

From the noise study most of the noise readings, in daytime and night, were higher than 55 dBA. This is the result of cars, trucks, motorcycles, and jet plane movements in the area. Since this level of noise is common to the area, most residents probably are accustomed to a noise level of 55 dBA. Complaints about increased noise levels due to train movements are expected to become more popular as the train moves more frequent through Morehead City.

Although the entire area near the tracks will be affected by the noise caused by trains, residents from 18th Street westward will tend to have higher noise levels and more complaints can be expected from this area. This is because more residential houses are located in the west of 18th Street and the higher speeds as the trains pass this area. Lower train speeds were observed near the port as the trains are moving toward and away from the State Port.

As it stands today with 2 trains per day moving through the City, residents have become accustomed to the trains and the noise being generated. As yearly coal tonnages increase the frequency of trains per day and the occurrance of the noise will increase. It is likely that more complaints about the trains noise will be expressed by local residents.

Less increase of noise level was observed for trains moving through the Town of Morehead City during the daytime, the train noise is expected to be less noticeable if it is scheduled to pass through the Town during the day.

V. VIBRATION IMPACT STUDY

In accordance with the contract, a vibration study was conducted to assess the possible impact that could result from increased coal train movements through Morehead City. The town officials of Morehead City are concerned about the possible adverse effects that train vibration could have to the water and wastewater lines near the railroad.

V.1. Location of Vibration Measurements

Vibration measurements were collected in June of 1982 by North Carolina Department of Transportation (NCDOT) and Wang Engineering. These measurements recorded the ground soil particle velocity as an indicator of the vehicular traffic and train vibrations at various locations and distances from the railroad tracks. Vehicular traffic and train vibration measurements were taken so that a comparison could be made in order to reach a conclusion about the possible adverse effects of coal transportation through the City. The location and description of these measurements are shown on Map 3 and in Table 11. A total of 12 tapes were collected for the field vibration measurements. However, because the poor quality of records for tapes 1, 2, 3, 4, 5, and 11, these tapes were not analyzed. The calculation of peak particle velocities for tapes 6, 7, 8, 9, 10, and 12 is shown in Appendix E. The vibration at designated locations was measured by Engineering Seismograph Model VS-1100.

V.2. The Analysis of Vibration Measurements and Results

The ground particle wave velocity measurements due to vibration were recorded on photographic paper called motion traces. These traces sketched the amplitude of vibration wave velocities for transverse (t), vertical (v), and longitudinal (l) motions. The maximum amplitudes of the traces were measured in inches with adjustable gains. The peak particle velocity (V_p) is calculated by following equation:

$$V_p = \sqrt{V_t^2 + V_v^2 + V_l^2} \quad \text{in./sec.}$$

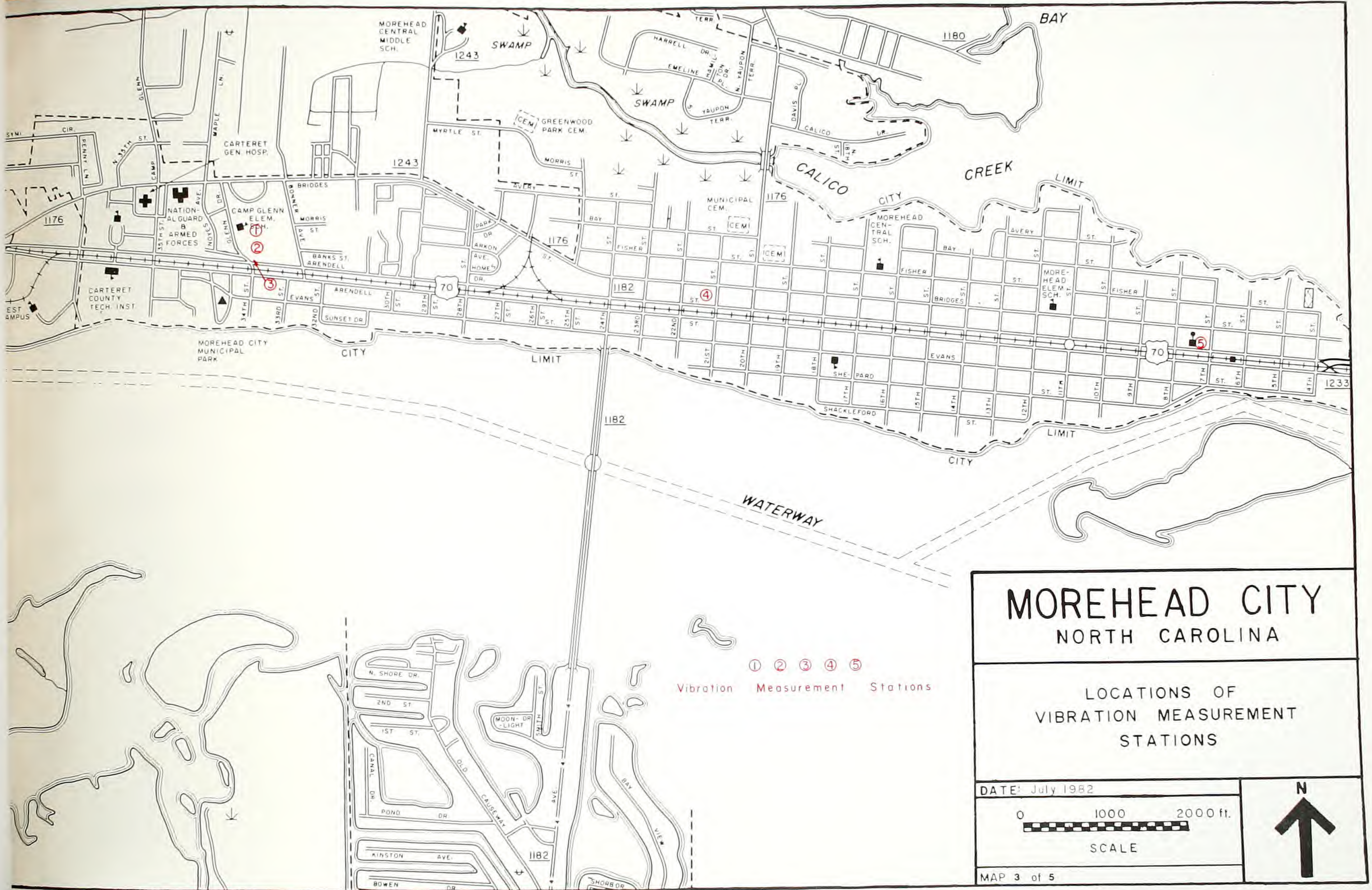

MOREHEAD CITY
NORTH CAROLINA
LOCATIONS OF VIBRATION MEASUREMENT STATIONS
DATE: July 1982
0 1000 2000 ft.
SCALE
MAP 3 of 5
N
① ② ③ ④ ⑤
Vibration Measurement Stations
CALICO CREEK
WATERWAY
SWAMP
BAY
CITY LIMIT
MOREHEAD CITY MUNICIPAL PARK
CARTERET GEN. HOSP.
CARTERET COUNTY TECH. INST.
CAMP GLENN ELEM. SCH.
NATIONAL GUARD & ARMED FORCES
MOREHEAD CENTRAL MIDDLE SCH.
MOREHEAD CENTRAL SCH.
MOREHEAD ELEM. SCH.
GREENWOOD PARK CEM.
MUNICIPAL CEM.
ARENDELL
EVANS
BRIDGES
FISHER
SHEPARD
SHACKLEFORD
70
1176
1182
1243
1180
1233

Table 11 Location and Discription of Soil Particle Wave Velocity Measurements Due to Vibration

Vibration Measurement Station See map	Tape#	Location	Date	Gain	Approx. Time of Tape	Remarks
2	1	55' N. of R.R. Tracks Inside school yard	6/22/82	5	120 sec.	Train Vibration
1	2	100' N. of R.R. Tracks Inside school yard	6/22/82	20	120 sec.	Train Vibration
2	3	55' N. of R.R. Tracks Inside school yard	6/22/82	5	40 sec.	Traffic Vibration
1	4	100' N. of R.R. Tracks Inside school yard	6/22/82	20	40 sec.	Traffic Vibration
4	5	88' from R.R. Tracks Arendell & 21th St. at Mayor's house	6/22/82	20	40 sec.	Train Vibration
3	6	11' N. of outside rail of R.R. 19' S. centerline of Arendell St. 529' W. of Bonner St.	6/23/82	1	130 sec.	Train Vibration
3	7	Same as Tape #6	6/23/82	20	78 sec.	Traffic Vibration
2	8	Same as Tape #1	6/23/82	20	38 sec.	Traffic Vibration
1	9	Same as Tape #2	6/23/82	20	17 sec.	Traffic Vibration
1	10	Same as Tape #2	6/23/82	20	14 sec.	Traffic Vibration
1	11	Same as Tape #2	6/23/82	20	29 sec.	Traffic Vibration
5	12	60' N. of outside rail of R.R. S.E. corner City Hall	6/23/82	5	120 sec.	Train Vibration

The particle peak velocity, V_p, was calculated from the values of V_t, V_v, and V_l which were measured at different distances from the rail tracks with different traffic conditions. Various types of traffic were monitored, such as cars, semi-tractor trailer trucks, and trains. The average V_p for cars at 11 ft. from the railroad was 0.003 in./sec., 0.0022 in./sec. at 55 ft. from the railroad, and 0.0018 in./sec. at 100 ft. from the railroad. The measurements of semi-tractor trailer trucks were at distances of 11 ft. and 55 ft. from the railroad in which average readings of 0.0161 in./sec. and 0.0096 in./sec. respectively, were collected. The average levels of vibration caused by trains were 0.3590 in./sec. and 0.0390 in./sec. at 11 ft. and 60 ft. respectively from the railroad. The summary of calculated average peak particle velocity is shown in Tables 12 and 13. To compare the difference between traffic and train vibrations, the results of the data were graphed. Figure 3 shows a plot of peak particle velocity versus accumulated probability. This graph shows a distinct difference in the magnitude between traffic and train vibrations; most of the peak particle vibration velocities due to train movements is above 0.02 in./sec. At 11 ft. from the railroad tracks 80 percent of probability is for the peak particle velocity in the range of 0.2 in./sec. to 0.8 in./sec. For vibration due to highway traffic, there is no significant difference of peak particle velocities between 11 ft. and 55 ft. from the railroad tracks. This is because the fact that 11 ft. from the tracks is actually 19 ft. from the centerline of the highway (southside), while 55 ft. from the tracks is 25 ft. from the centerline of the highway (northside). At 100 ft. from the railroad track, or 70 ft. from the highway centerline, the peak particle velocity does not exceed 0.002 in./sec.

The equation of $V = kD^{-n}$ was reported by Wiss, where V is the peak particle velocity (in./sec.), D is the distance in ft., and k and n are constants. Figure 4 shows the relationship between the peak particle velocity and the distance from the vibration source. Theoretically, a linear relationship on log - log paper was observed (Wiss). The actual measurement data indicate that a linear log - log relationship was found for trains and particularly the highway traffic causing vibration.

In general, the average and maximum peak particle velocities attributed to train movements are more than ten times greater than those of traffic vehicles. The approximate peak particle velocity beyond 100 ft. from the railroad can be estimated by extrapolating the existing lines.

The amount of energy the vibrating waves possess is also a log - log linear function with the peak particle velocity. Wiss reported a typical form of $V = C(E)^d$, where V is the peak particle velocity, E is the vibration energy, and C and d are constants. The closer to the vibrating object, the more vibration and energy impact the wave will have, but as the wave travels through the earth, some of the energy will be dissipated by the soil. This is a major factor in assessing the

Figure 3 Calculated Peak Particle Velocity Versus Accumulated Probability Derived from Vibration Measurements Along the Railroad

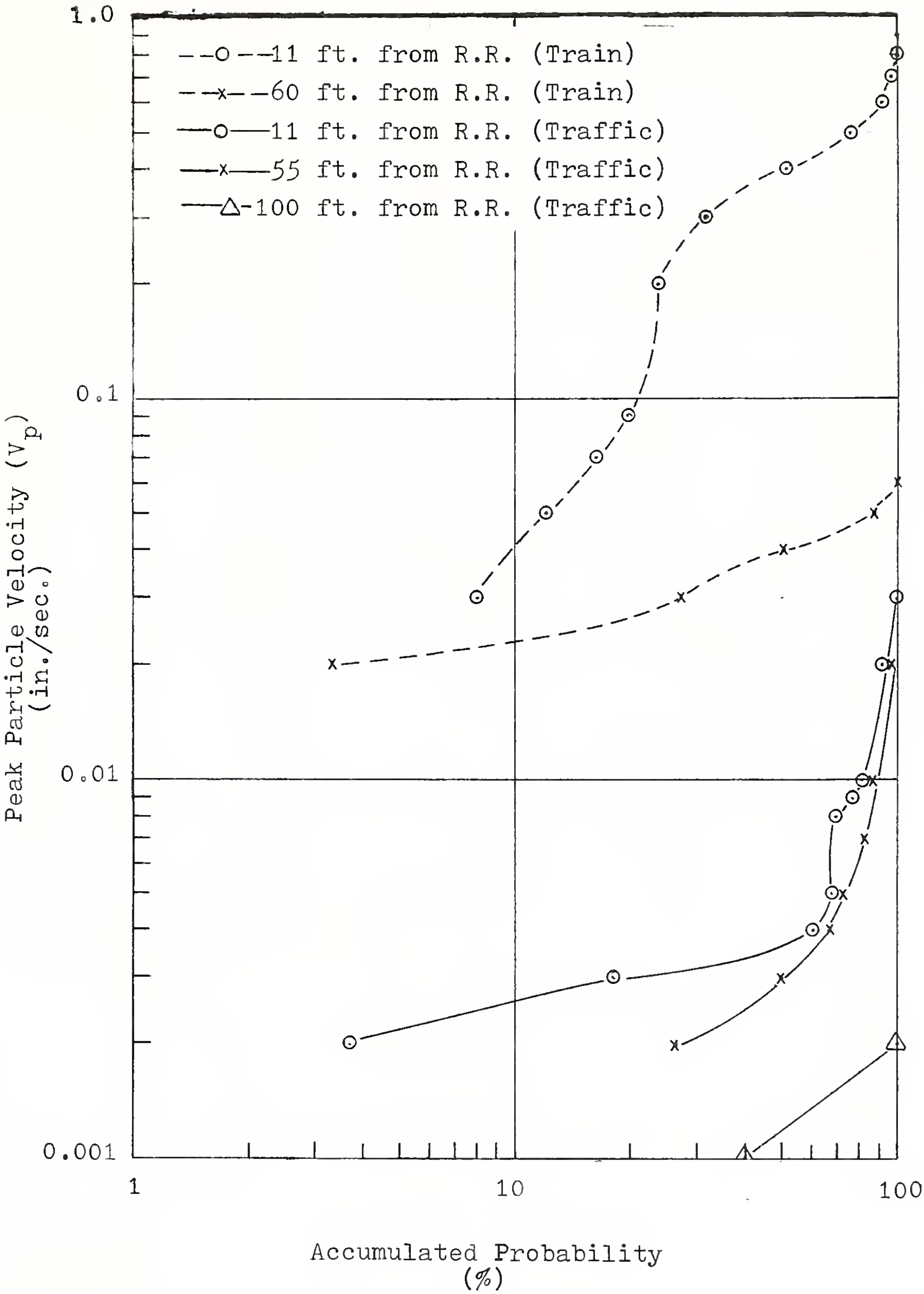


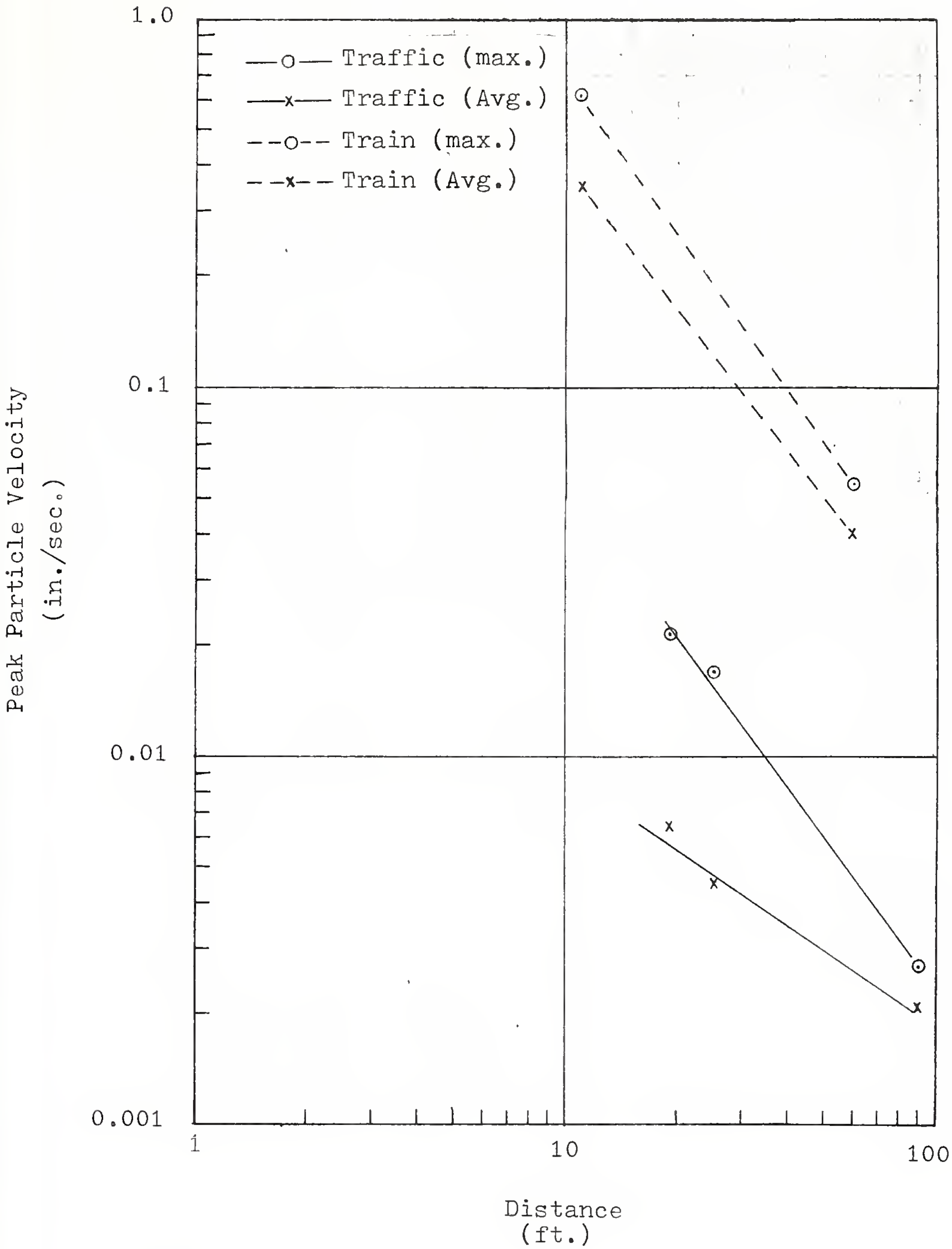
Table 12 Average Particle Velocities Calculated from Vehicular Traffic Vibration Data

Type of vehicle	Distance from centerline of Arendell St.		
	19 ft.	25 ft.	89 ft.
Cars	0.003	0.0022	0.0019
Semi-tractor trailer trucks	0.0161	0.0096	No Data Recorded

Table 13 Average Particle Velocities Calculated from Train Vibration Data

Type of train car	Distance from railroad	
	11 ft.	60 ft.
Engine	0.5546	0.0421
Loaded hopper (coal)	No Data Recorded	0.0269
Empty hopper	0.3418	No Data Recorded
Loaded tank and box	0.4104	No Data Recorded

Figure 4. The Delineation of Peak Particle Velocity Due to Vibration Versus Distance from Vibration Source



possible impact due to the train vibrations. The closer a structure is to the railroad, the more energy it will be subjected to, thus giving the structure a higher chance of encurring damage.

V.3. Impact and Considerations of Vibration Attributed to Train Transportation

Several factors can affect the magnitude and impact of train vibrations; the weight of the train cars, speed of the trains, braking and acceleration of the trains, condition of the railroad bed, thickness of the railroad bed, nature of the soil underlying the railroad bed, distance from the railroad bed to the structure where vibrations are experienced, and the frequency to which the vibrations occur. These are important aspects to consider in assessing the possible effects of the train vibrations.

V.3.1. The Weight of Train Cars

The trains that were monitored for the vibration study usually consisted of an engine, hopper cars used for coal transportation, tank cars, and box cars. From analysis of the vibration study, the magnitude of the vibrations due to coal hopper cars exceeded that of tank and box cars, although the engines caused the highest amount of vibration due to the weight of the engines used to power the trains. The increase in vibration of hopper cars over that of tank and box cars is observed. This is due to the increase of train car weight when loaded with coal. The impact difference is shown in Table 13. Thus, as more coal is exported through Morehead City, the trains will begin to consist of more coal hopper cars and an increase in vibration can be expected.

V.3.2. The Train Speed

The speed of the train also influences the amount of vibration it produces. When the train encounters a bump or unevenness in the track, the faster the speed of the train the more the train will jump on the tracks. As the train jumps or bounces on the rails, it imparts energy to the ground causing vibration. The more the bounce the greater the transmission of energy to the ground and increased amplitude of vibration. To decrease the amount of vibration, trains could be required to go through the City at slower speeds, but this will result in more traffic delays and emergency services delays as mentioned previously.

V.3.3. The Train Braking and Acceleration

Braking and acceleration of trains will effect the amount of vibration caused much in the same as the speed does. When a train is accelerating, the vibration from the train will be less than or no more than when the train is free running at higher speed. When the train is braking, vibration should also be reduced, unless while braking the train brakes are applied too vigorously, causing the train to jerk the wheels to a stop. If the wheels are suddenly stopped the momentum of the train will cause it to bounce on the track, thus resulting in more vibration than when the train is brought smoothly to a stop.

V.3.4. The Railroad Bed

The condition of the railroad bed is a major factor influencing train vibration. If the rails are uneven and cause the train to bounce on the track, an increase in vibration will occur. Southern Railroad rebuilt the railroad going through Morehead City in early 1982. The rails were welded together to make the railroad bed much smoother. Comments from local officials and residents have stated that vibration caused by the trains has been substantially reduced.

Sutherland reported that the thicker the railroad bed, the less the vibration was observed. When Southern Railroad rebuilt the railroad bed in early 1982, more gravel was added to the railroad, helping reduce the vibration caused by the trains. In the future when further repairs of the railroad bed are made, thickening the railroad bed with trenches along both sides of the road bed could be considered to further reduce the vibration.

V.3.5. Soil Conditions

The nature of the underlying soil around the railroad effects the impact of vibration because different soils transmit vibration in different ways. Listed are the natural vibrating frequencies of earth materials (Wiss and Steffens).

Earth Material	Natural Frequency (Hz)
Loose, Alluvium, Peaty and Silty Soil	5 to 10
Clay, Soft to Stiff	15 to 25
Sand	30 to 40
Rock	40 to 90

Morehead City, located in the coastal zone, has sandy loam as its predominant soil with a natural frequency of 30 to 40 Hz.

In a recent study it was reported that rail traffic has a vibration frequency between 10 and 100 Hz (Northwood). Comparing this frequency to that of the sandy soil shows that usually train frequencies will be equal to or higher than that of the soil. Thus the soil will be able to attenuate the vibration, and reduce the adverse effects of the train vibrations.

V.3.6. Distance from the Train Tracks

Due to the sandy soils ability to attenuate the train vibrations, the further the distance away from the railroad the less the vibration energy will be received. This is a crucial factor in assessing the damage the train vibrations could cause to the water and wastewater lines. Thus, the water and wastewater lines which are placed parallel to the railroad and the portion of the lines directly underneath the railroad will be the most effected. The relationship of peak particle velocity and the distance from the vibration source is shown in Figure 4.

V.3.7. Train Frequency in Morehead City

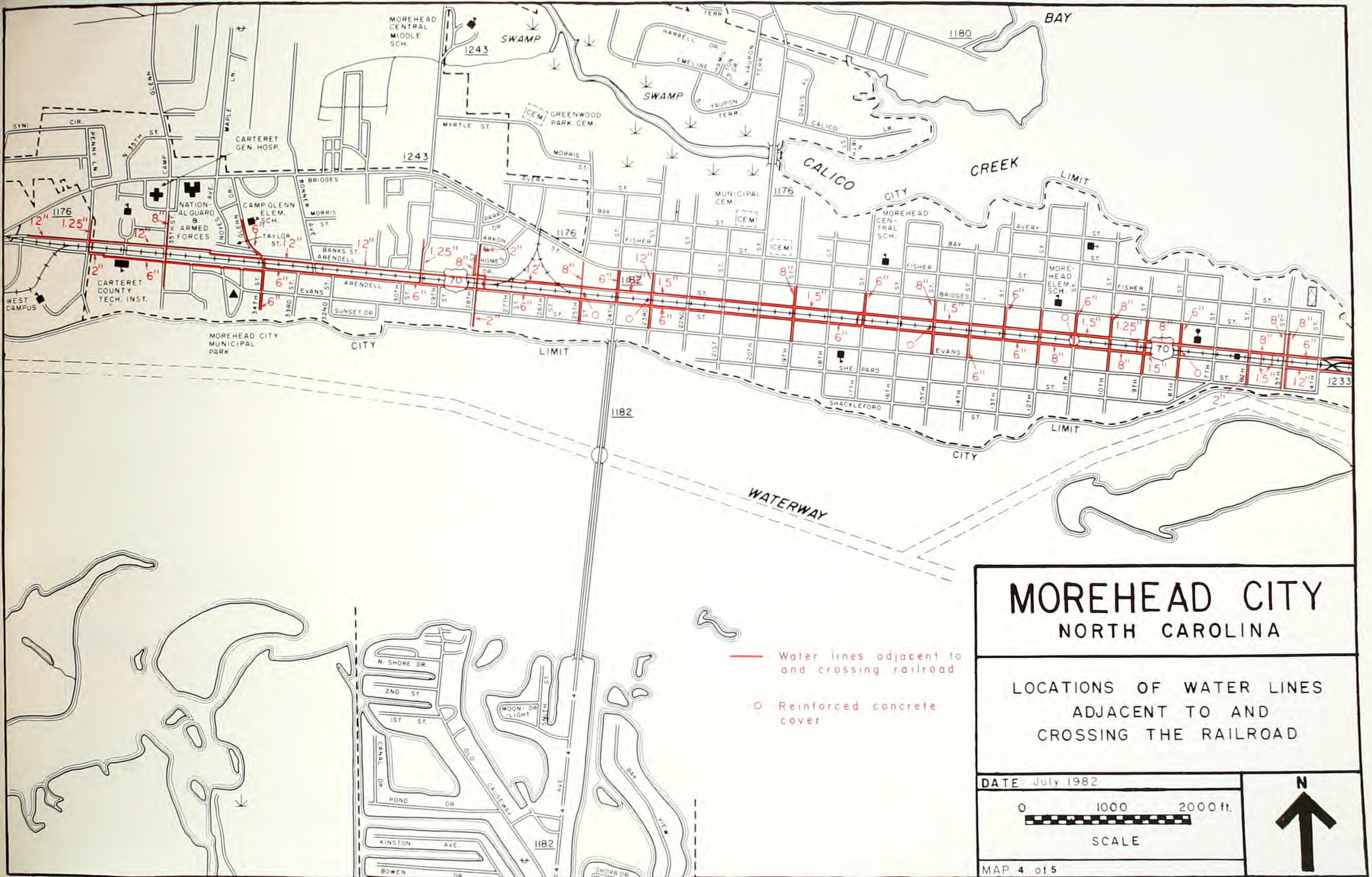
As it stands today with 3 million tons of coal per year being transported through Morehead City, or two coal trains per day passing through the City, the frequency to which the train vibrations occur is considered to be low and combined with the attenuating effect the sandy soil has on the vibrations, the effect of the vibrations on the water and wastewater lines which have a certain distance from the railroad tracks is limited. However, the water and sewer pipes and joints adjacent to the railroad tracks will receive significant impact from the vibration due to train movement. As the frequency of the trains increases so does the vibrations. Therefore, with an increase in the frequency of the vibrations, the energy from these vibrations could be more frequently imparted to the pipes and joints of the water and sewer system. This could eventually cause pipes to crack and joints to loosen, resulting in a failure in the water and wastewater systems. The detailed analysis will be followed in the subsequent sections.

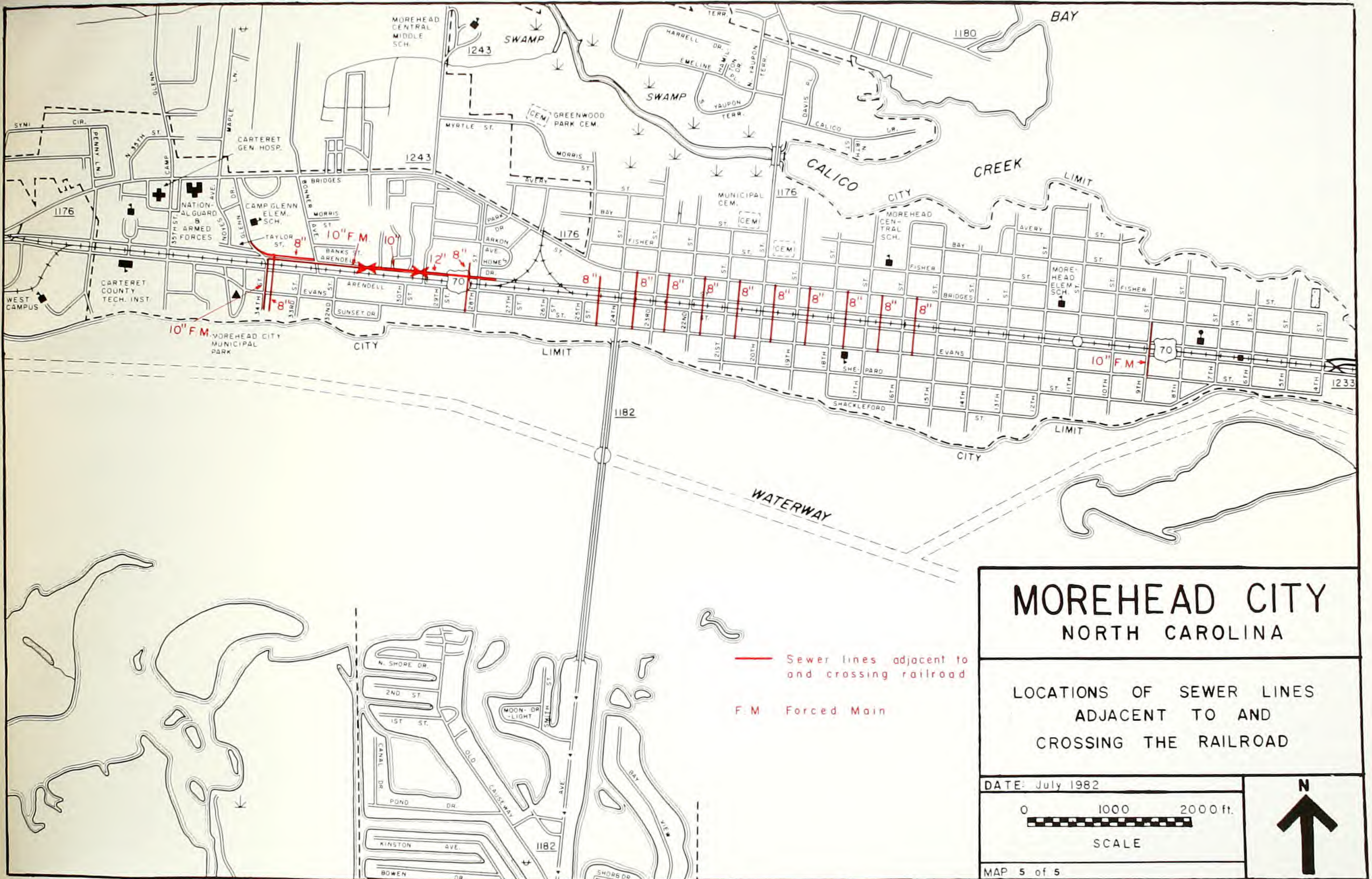
V.4. <u>Water and Wastewater Lines Adjacent to the Railroad Tracks</u>

The data of location, size, and depth of the water and wastewater lines near the railroad tracks was collected from the Town of Morehead City. The location and sizes of the water and wastewater lines are shown on Maps 4 and 5.

Water lines which are located under Arendell Street and parallel to the railroad tracks are listed as follows: 100 ft. of 1 1/4 in. line, 7700 ft. of 1 1/2 in. line, 12,300 ft. of 6 in. line, 3,450 ft. of 8 in. line, and 8,300 ft. of 12 in. line.

There are 25 locations where the water lines cross the railroad tracks. Five water lines which cross the railroad tracks are encased in steel culverts, 4 of which are 8 in. line and one 12 in. line. These water lines average 6 feet in depth. The other water lines which cross the railroad tracks are listed as follows: 3 of 1 1/4 in. lines, 4 of 1 1/2 in. lines, 2 of 2 in. lines, 7 of 6 in. lines, and 4 of 8 in. lines. These water lines average 3 feet in depth. All the water lines in Morehead City are either copper, galvanized, asbestos cement, cast iron, or ductile iron pipes.


MOREHEAD CITY
NORTH CAROLINA
LOCATIONS OF WATER LINES ADJACENT TO AND CROSSING THE RAILROAD
DATE July 1982
0 1000 2000 ft.
SCALE
N
MAP 4 of 5
Water lines adjacent to and crossing railroad
Reinforced concrete cover
BAY
SWAMP
CALICO CREEK
WATERWAY
CITY LIMIT
MOREHEAD CENTRAL MIDDLE SCH.
GREENWOOD PARK CEM.
CARTERET GEN. HOSP.
NATIONAL GUARD & ARMED FORCES
CAMP GLENN ELEM. SCH.
CARTERET COUNTY TECH. INST.
WEST CAMPUS
MOREHEAD CITY MUNICIPAL PARK
MUNICIPAL CEM.
MOREHEAD CENTRAL SCH.
MOREHEAD ELEM. SCH.
ARENDELL
EVANS ST.
BRIDGES ST.
FISHER ST.
SHACKLEFORD ST.
N. SHORE DR.
OLD CAUSEWAY
KINSTON AVE.
BOWEN DR.
1176
1182
1243
1180
1233
70


MOREHEAD CITY
NORTH CAROLINA
LOCATIONS OF SEWER LINES ADJACENT TO AND CROSSING THE RAILROAD
DATE: July 1982
0 1000 2000 ft.
SCALE
N
MAP 5 of 5
Sewer lines adjacent to and crossing railroad
F.M. Forced Main
10" F.M.
8"
12"
10"
SWAMP
CALICO CREEK
BAY
WATERWAY
CITY LIMIT
MOREHEAD CENTRAL MIDDLE SCH.
CARTERET GEN. HOSP.
NATIONAL GUARD & ARMED FORCES
CAMP GLENN ELEM. SCH.
CARTERET COUNTY TECH. INST.
WEST CAMPUS
MOREHEAD CITY MUNICIPAL PARK
GREENWOOD PARK CEM.
MUNICIPAL CEM.
MOREHEAD CENTRAL SCH.
MOREHEAD ELEM. SCH.
ARENDELL
EVANS
BRIDGES
FISHER
SHACKLEFORD
1176
1243
1182
1180
1233
70

The wastewater lines are shown on Map 5. These wastewater lines consist of clay pipes for gravity flow, and asbestos cement for pressurized lines.

Wastewater lines which are located under Arendell Street and parallel to the railroad tracks are listed as follows: 1,000 ft. of 12 in. gravity flow line, 600 ft. of 10 in. gravity flow line, 600 ft. of 8 in. gravity flow line, and 1,200 ft. of 10 in. pressurized line.

There are 14 locations where the wastewater lines cross the railroad tracks. Two of these lines are pressurized lines and are shown on Map 5 as 10 in. Forced Main (F.M.). The other 12 wastewater lines which cross the tracks are 8 in. lines made from clay. The average depth of the wastewater lines is about 6 feet.

V.5. Emergency Repair Materials for Water and Wastewater Systems

The engineering analysis indicates that the frequency of coal train movements will definitely generate higher vibration impact to the water and wastewater lines adjacent to the railroad tracks.

In the event of a broken water or wastewater line, it will be time consuming to obtain the appropriate parts and material from suppliers for repairment purposes. Joe Clayton, the Director of the Department of Utilities in Morehead City has suggested purchasing emergency repair materials to reduce the mitigation time. The following list of repair materials has been suggested:

Water Lines

200 ft. of 6 in. Ductile Iron pipe

30 ft. of 8 in. Ductile Iron pipe

20 - 6 in. Bell Joint Clamps

5 - 8 in. Bell Joint Clamps

Wastewater Lines

60 ft. of 14 in. Ductile Iron pipe

60 ft. of 10 in. Ductile Iron pipe

4 Asbestos Cement to Ductile Iron Trans Couplings

2 - 8 in. Clay to Ductile Iron Fernco Adapters

1 - 10 in. Repair Clamp

If the water or wastewater lines fail, particularly for those underneath the railroad, the train movements could be delayed. It would be advantageous to the train transportation if the emergency repair parts can be purchased and stored to save the repair time. Consequently, it is conceivable to receive the financial aid to purchase these repair materials from the resources derived from coal exportation or other train transportation related activities.

V.6. Discussion

Through the comprehensive field data collection and engineering analysis, the following observations and conclusions are derived:

1. The peak soil particle velocity attributed to vibration from train movement is substantially higher than that generated from vehicular traffic. The train engine generates higher vibration than loaded hoppers which also produce higher vibrations than box cars and empty hoppers.

2. The train vibration impact to above ground structures is minimal (Figure 5). Nevertheless, the effects of train vibration upon residence adjacent to Arendell Street range from just perceptible to easily noticeable (Figure 6).

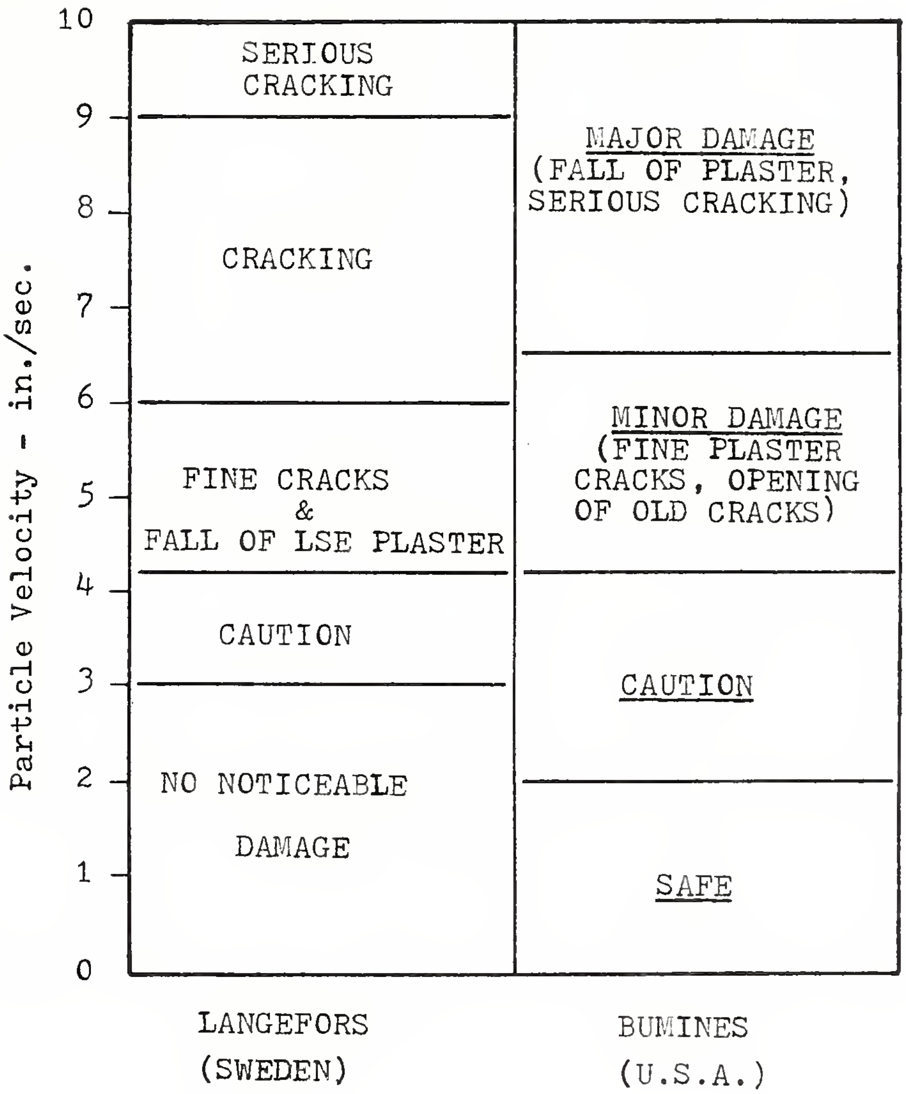
3. No historical evidence indicates the train vibration will have direct cracking effects to the existing water and wastewater lines. Further study should be conducted. However, the higher vibration peak particle velocity in combination with water table changes could cause the uneven settlement of soil underneath the water and wastewater lines in a gradual fashion; a bending force can be created at the joints and along pipes. The more frequent train movements can accelerate this process. Eventual failures at some points could be experienced.

4. The improvement of railroad beds by Southern Railway should have had a positive impact to the impairment of train vibration. The slower train speeds, smooth rails, and thick rail bed will reduce the vibration magnitude.

5. It is conceivable to purchase and store the parts and materials for emergency repair purposes, in case the water or wastewater line or joint fails.

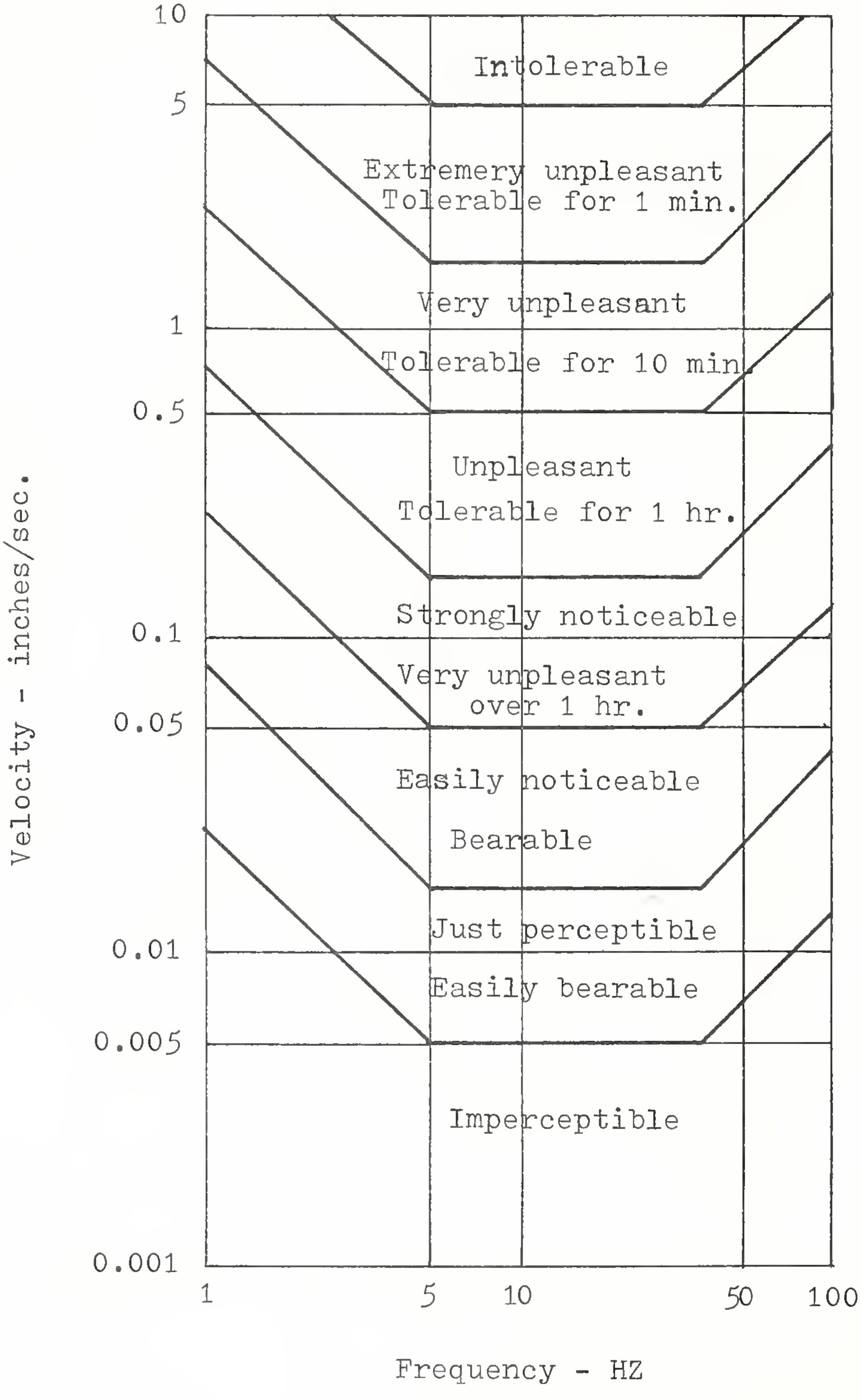
6. With the attenuation of vibration by the soil, the impact of coal train vibration to water and wastewater lines located outside of Arendell Street is very limited.

Figure 5. Relationship Between Particle Velocity and Residential Structural Damage



Wiss, John F., Journal of the Geotechnical Engineering Division. 1980

Figure 6. Effect of Vibration Upon Humans



VI. BUSINESS EFFECTS

The existing and increasing coal movements through Morehead City and exportation through Morehead Port have significant impact on the local business. The generation of job opportunities due to coal shipment and exportation at the Port, and coal train passing through the downtown of Morehead City will affect the business activities at the Town of Morehead City.

VI.1. General Business Background

At present, Morehead City is the largest town and retail trade center in Carteret County. The Town contains over 50 percent of the county's apparel and accessory stores. A Gross Retail Sales Chart for Carteret County, prepared by N. C. Department of Budget and Management is shown as follows:

	1978 - 1979	1980 - 1981
1% Retail	$ 1,028,562	$ 1,706,522
2% Auto, Planes, Boats	11,740,201	10,204,757
Apparel	3,065,955	3,397,879
Automobile	22,650,706	27,355,503
Food	58,193,859	77,876,509
Furniture	8,117,888	10,081,558
General Merchandise	26,483,868	34,234,233
Building Materials	11,512,447	12,111,085
Unclassified Group	31,398,236	38,081,705
TOTALS	$174,191,722	$215,049,751

The Town also serves as a tourist center for many visitors that travel to the coast each year. The Carteret County Economic Development Council developed a travel expenditure chart to show the growing tourist business in Carteret County.

Travel Expenditures	
1973	$ 8,607,000
1974	$ 9,117,000
1975	$ 9,714,000
1976	$ 1,007,000
1977	$15,200,000
1978	$16,937,000
1979	$17,038,000
1980	$18,685,000
1981	$22,362,000

The Morehead State Port business has a direct and important impact on the local economy. The business statistics for the Morehead Port indicated that the total revenue has increased steadily during recent years:

	General Cargo		Asphalt and		
	Import	Export	Petroleum	Military	Total
1974	$538,683.74	$559,680.80	$252,537.28	$5,623.28	$1,356,525.50
1975	395,133.36	610,823.58	156,375.39	3,192.84	1,165,525.17
1976	718,409.66	764,535.07	141,388.36	11,594.03	1,635,926.92
1977	160,087.54	871,251.36	708,604.22	4,962.70	1,744,905.82
1978	275,308.36	947,665.29	771,218.42	23,380.97	2,017,573.04

Substantial increase of business revenue for the Morehead Port is expected due to the addition of coal exportation.

VI.2. Business Impact at Morehead City

The coal export activities have a definite positive impact to the coal company, railroad company and Morehead State Port Authority. However, both positive and negative business effects to the Town of Morehead City are observed. The positive effect includes the job opportunities being generated at the Morehead City Port and adjacent areas, and the construction, daily operation requirement, business associated with the coal exportation. However, the negative impact consists of the traffic delay, noise and vibration effects on the downtown and tourist business.

In accordance with a report prepared by Sam Holcomb of Alla - Ohio Valley Coals, Inc., additional revenue of $1.12 million for 1981, $2.76 million for 1982 and 1983 can be generated for Morehead City Port due to the lease agreement and coal ship charges. Fifty-three new jobs associated with steam coal exportation have been created at State Port Authority, Morehead Coal Terminal, Inc., Hampton Roads Testing, and Alla-Ohio Valley Coals, Inc., in the Morehead City Port area. $2.75 million of construction and supply related businesses have been brought to North Carolina companies and enterprises. According to a study conducted by Paul Tschetter, each ton of coal shipped from North Carolina generated approximately $5.55 for the local community and $0.87 for the Morehead City Port in 1981. In 1982 and 1983, those per tons benefits are $2.31 and $2.27 respectively for the local community and $0.92 each year for the Morehead City Port.

The train has been passing through Morehead City one or two times a day since the local residents can remember. The existing condition of 3 million tons per year, particularly with arrangement of mix trains, does not seem to have a significant negative impact to local business. If the tonnages substantially increase, for example 15 million tons per year, there will be 50 minutes daily traffic delays assuming average train speed of 10 m.p.h. (Table 8). The downtown and tourist related independent shops located along Arendell Street on the east side of the City could suffer serious losses of business because of the increased coal train traffic. Before a substantial increase of coal trains is allowed to pass through Morehead City, a detailed study of the impact to downtown businesses should be performed.

VII. REFERENCES

Barton-Aschman Asso., R. L. Banks Asso., and Ernst and Whinney. "Alternative Solutions to Railroad Impacts on Communities." Minnesota Department of Transportation, North Dakota State Highway Department. Phase II Technical Report: Case Studies. June 1980.

Brower, McElyer, Godschalk, and Lofaro. "Outer Continental Shelf Development and the North Carolina Coast: A Guide for Local Planners." North Carolina Coastal Energy Impact Program, North Carolina Department of Natural Resources and Community Development. August 1981.

Cribbins, Paul D. "Coastal Energy Transportation Study: An Analysis of State and Federal Policies in North Carolina's Coastal Zone." UNC Institute for Transportation Research and Education. Phase II, Volume 3. August 1981.

Cribbins, Paul D. "Coastal Energy Transportation Study: A Study of OCS Onshore Support Bases and Coal Export Terminals." North Carolina Coastal Energy Impact Program, North Carolina Department of Natural Resources and Community Development. August 1981.

Delon Hamton Asso. "The Environmental Impact of Coal Transfer and Terminal Operations." U. S. Department of Commerce: National Technical Information Service. October 1980.

Dym, Clive L. "Attenuation of Ground Vibration." <u>Sound and Vibration</u>. pp. 32-34, April 1974.

Hauser, Cribbins, Tschetter, and Latta. "Coastal Energy Transportation Needs to Support Major Energy Projects in North Carolina's Coastal Zone." North Carolina Coastal Energy Impact Program, North Carolina Department of Natural Resources and Community Development. December 1980.

Kinner, Liu, and Yegian. "Ground Vibrations." <u>Sound and Vibration</u>. pp. 26-32, October 1974.

N. C. Department of Transportation. "Additional Coal Shipments Through Morehead City and New Bern. An Investigation of Alternative Methods and Routes." June 1982.

N. C. Department of Transportation. "Coal Train Movements Through the City of New Bern." Transportation Planning Division, March 1981.

N. C. Department of Transportation. "Impact of Coal Train Movements on Vehicular Circulation in Morehead City Area." Thoroughfare Planning Unit, December 1981.

N. C. Marine Science Council. "North Carolina and the Sea: Planning Report for the Development of North Carolina's Coastal Area Resources." June 1980.

Northwood, T. D. "Isolation of Building Structures from Ground Vibration." ASME Design Engineering Conference, Isolation of Mechanical Vibration Impact and Noise, September 1973.

Roberts and Eichler Asso. "Area Development Plan for Radio Island." North Carolina Coastal Energy Impact Program. North Carolina Department of Natural Resources and Community Development. June 1982.

Rogers, Golden, and Halpern. "Mitigating the Impact of Energy Facilities: A Local Air Quality Program for the Wilmington, North Carolina Area." North Carolina Coastal Energy Impact Program, North Carolina Department of Natural Resources and Community Development. January 1981.

Sawada and Tanigughi. "Attenuation with Distance of Traffic Induced Vibrations." Soils and Foundations, Volume 19, pp. 15-28, June 1979.

Steffens, R. J. "Some Aspects of Structural Vibration." Symposium Vibration in Civil Engineering, London. 1966.

Sutherland, Hugh B. "A Study of Vibration Produced in Structures by Heavy Vehicles." University of Glasgow, Scotland.

U. S. Environmental Protection Agency. "Information on Levels of Environmental Noise Requiste to Protect Public Health and Welfare with Adequate Margin of Safety." March 1974.

U. S. Environmental Protection Agency. "Railroad Noise Emission Standards." January 1976.

U. S. Environmental Protection Agency. "Background Document for Railroad Noise Emission Standards." December 1975.

Wiss, John. "Construction Vibration: State of the Art." Journal of Geotechnical Engineering Division. ASCE. pp. 167-179, April 1980.

Wiss, John. "Damage Effects of Pile Driving Vibration." Highway Research Project Report No. 155, 1967.

CEIP Publications

1. Hauser, E. W., P. D. Cribbins, P. D. Tschetter, and R. D. Latta. Coastal Energy Transportation Needs to Support Major Energy Projects in North Carolina's Coastal Zone. CEIP Report #1. September 1981. $10.

2. P. D. Cribbins. A Study of OCS Onshore Support Bases and Coal Export Terminals. CEIP Report #2. September 1981. $10.

3. Tschetter, P. D., M. Fisch, and R. D. Latta. An Assessment of Potential Impacts of Energy-Related Transportation Developments on North Carolina's Coastal Zone. CEIP Report #3. July 1981. $10.

4. Cribbins, P. S. An Analysis of State and Federal Policies Affecting Major Energy Projects in North Carolina's Coastal Zone. CEIP Report #4. September 1981. $10.

5. Brower, David, W. D. McElyea, D. R. Godschalk, and N. D. Lofaro. Outer Continental Shelf Development and the North Carolina Coast: A Guide for Local Planners. CEIP Report #5. August 1981. $10.

6. Rogers, Golden and Halpern, Inc., and Engineers for Energy and the Environment, Inc. Mitigating the Impacts of Energy Facilities: A Local Air Quality Program for the Wilmington, N. C. Area. CEIP Report #6. September 1981. $10.

7. Richardson, C. J. (editor). Pocosin Wetlands: an Integrated Analysis of Coastal Plain Freshwater Bogs in North Carolina. Stroudsburg (Pa): Hutchinson Ross. 364 pp. $25. Available from School of Forestry, Duke University, Durham, N. C. 27709. (This proceedings volume is for a conference partially funded by N. C. CEIP. It replaces the N. C. Peat Sourcebook in this publication list.)

8. McDonald, C. B. and A. M. Ash. Natural Areas Inventory of Tyrrell County, N. C. CEIP Report #8. October 1981. $10.

9. Fussell, J., and E. J. Wilson. Natural Areas Inventory of Carteret County, N. C. CEIP Report #9. October 1981. $10.

10. Nyfong, T. D. Natural Areas Inventory of Brunswick County, N. C. CEIP Report #10. October 1981. $10.

11. Leonard, S. W., and R. J. Davis. Natural Areas Inventory for Pender County, N. C. CEIP Report #11. October 1981. $10.

12. Cribbins, Paul D., and Latta, R. Daniel. Coastal Energy Transportation Study: Alternative Technologies for Transporting and Handling Export Coal. CEIP Report #12. January 1982. $10.

13. Creveling, Kenneth. Beach Communities and Oil Spills: Environmental and Economic Consequences for Brunswick County, N. C. CEIP Report #13. May 1982. $10.

14. Rogers, Golden and Halpern, Inc., and Engineers for Energy and the Environment. The Design of a Planning Program to Help Mitigate Energy Facility-Related Air Quality Impacts in the Washington County, North Carolina Area. CEIP Report #14. September 1982. $10.

16. Frost, Cecil C. Natural Areas Inventory of Gates County, North Carolina. CEIP Report #16. April 1982. $10.

17. Stone, John R., Michael T. Stanley, and Paul T. Tschetter. Coastal Energy Transportation Study, Phase III, Volume 3: Impacts of Increased Rail Traffic on Communities in Eastern North Carolina. CEIP Report #17. August 1982. $10.

19. Pate, Preston P., and Jones, Robert. Effects of Upland Drainage on Estuarine Nursery Areas of Pamlico Sound, North Carolina. CEIP Report #19. December 1981. $1.00.

25. Wang Engineering Co., Inc. Analysis of the Impact of Coal Trains Moving Through Morehead City, North Carolina. CEIP Report #25. October 1982. $10.

26. Anderson & Associates, Inc. Coal Train Movements Through the City of Wilmington, North Carolina. CEIP Report #26. October 1982. $10.

27. Peacock, S. Lance and J. Merrill Lynch. Natural Areas Inventory of Mainland Dare County, North Carolina. CEIP Report #27. November 1982. $10.

28. Lynch, J. Merrill and S. Lance Peacock. Natural Areas Inventory of Hyde County, North Carolina. CEIP Report #28. October 1982. $10.

29. Peacock, S. Lance and J. Merrill Lynch. Natural Areas Inventory of Pamlico County, North Carolina. CEIP Report #29. November 1982. $10.

30. Lynch, J. Merrill and S. Lance Peacock. Natural Areas Inventory of Washington County, North Carolina. CEIP Report #30. October 1982. $10.

31. Muga, Bruce J. Review and Evaluation of Oil Spill Models for Application to North Carolina Waters. CEIP Report #31. August 1982. $10.

33. Sorrell, F. Yates and Richard R. Johnson. Oil and Gas Pipelines in Coastal North Carolina: Impacts and Routing Considerations. CEIP Report #33. December 1982. $10.

34. Roberts and Eichler Associates, Inc. Area Development Plan for Radio Island. CEIP Report #34. June 1982. $10.

35. Cribbins, Paul D. Coastal Energy Transportation Study, Phase III, Volume 4: The Potential for Wide-Beam, Shallow-Draft Ships to Serve Coal and Other Bulk Commodity Terminals along the Cape Fear River. CEIP Report #35. August 1982. $10.